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LIQUID PENETRANT TESTING

Prepared under Contract NAS 8-20185 by

Convair Division
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Liquid Penetrant Testing

CR61205

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PREFACE

~~Programmed Instruction Handbook~~ Liquid Penetrant Testing ~~(5330.10)~~ is home study material for familiarization and orientation on Nondestructive Testing. ~~This material was planned and prepared for use with formal Nondestructive Testing courses. Although these courses are not scheduled at this time the material will be a valuable aid for familiarization with the basics of Nondestructive Testing. When used as prerequisite material, it will help standardize the level of knowledge and reduce classroom lecture time to a minimum.~~ The handbook has been prepared in a self-study format including self-examination questions.

It is intended that handbook ~~5330.9,~~ Introduction to Nondestructive Testing, be completed prior to reading other publications ~~Programmed Instruction Handbooks of the~~ in the Nondestructive ~~Testing~~ series. The material presented in these documents will provide much of the knowledge required to enable each person to perform his Nondestructive Testing job effectively. However, to master this knowledge considerable personal effort is required.

This Nondestructive Testing material is part of a large program to create an awareness of the high reliability requirements of the expanding space program. Highly complex hardware for operational research and development missions in the hazardous and, as yet, largely unknown environment of space makes it mandatory that quality and reliability be developed to levels heretofore unknown. The failure of a single article or component on a single mission may involve the loss of equipment valued at many millions of dollars, not to mention possible loss of lives, and the loss of valuable time in our space timetable.

A major share of the responsibility for assuring such high levels of reliability, lies with NASA, other Government agencies, and contractor Nondestructive Testing personnel. These are the people who conduct or monitor the tests that ultimately confirm or reject each piece of hardware before it is committed to its mission. There is no room for error -- no chance for reexamination. The decision must be right -- unquestionably -- the first time. This handbook is one step toward that goal.

General technical questions concerning this publication should be referred to the George C. Marshall Space Flight Center, Quality and Reliability Assurance Laboratory, Huntsville, Alabama 35812.

The recipient of this handbook is encouraged to submit recommendations for updating and comments for correction of errors in this initial compilation and to George C. Marshall Space Flight Center, Quality and Reliability Assurance Laboratory (R-QUAL-OT), Huntsville, Alabama 35812.

ACKNOWLEDGMENTS

This handbook was prepared by the Convair Division of General Dynamics Corporation under NASA Contract NAS8-20185. Assistance in the form of process data, technical reviews, and technical advice was provided by a great many companies and individuals. The following listing is an attempt to acknowledge this assistance and to express our gratitude for the high degree of interest exhibited by the firms, their representatives, and other individuals who, in many cases, gave considerable time and effort to the project.

Aerojet General Corp.; Automation Industries, Inc., Sperry Products Division; AVCO Corporation; The Boeing Company; Douglas Aircraft Co., Inc.; Grumman Aircraft; Lockheed Aircraft Corp.; Magnaflux Corp.; The Martin Co. (Denver); McDonnell Aircraft Corp.; Met-L-Check Co.; North American Aviation, Inc.; Rohr Corporation; Shannon Luminous Materials Co., Tracer-Tech Division; St. Louis Testing Laboratories, Inc.; Turco Products, Inc.; Uresco, Inc.; X-Ray Products Corp.

Our thanks is also extended to the many individuals who assisted in the testing of the materials to validate the teaching effectiveness. Their patience and comments contributed greatly to the successful completion of the handbook.

INTRODUCTION

This handbook presents the principles and applications of liquid penetrant testing. It will teach you the basic procedures that are used in liquid penetrant testing. In addition, you will learn the results that can be expected from a properly conducted test; how liquid penetrants work; the materials and equipment required; and the limitations of liquid penetrant testing.

The material is presented in one volume.

Prior to reading this handbook, the reader should have completed 5330.9, Introduction to Nondestructive Testing.

INSTRUCTIONS

The pages in this book should not be read consecutively as in a conventional book. You will be guided through the book as you read. For example, after reading page 3-12, you may find an instruction similar to one of the following at the bottom of the page —

- Turn to the next page
- Turn to page 3-15
- Return to page 3-10

On many pages you will be faced with a choice. For instance, you may find a statement or question at the bottom of the page together with two or more possible answers. Each answer will indicate a page number. You should choose the answer you think is correct and turn to the indicated page. That page will contain further instructions.

As you will soon see, it's very simple — just follow instructions.

As you progress through the book, ignore the back of each page. THEY ARE PRINTED UPSIDE DOWN. You will be instructed when to turn the book around and read the upside-down printed pages.

TURN TO THE NEXT PAGE

WHAT IS "LIQUID PENETRANT TESTING?" That's the first question to be answered by this book. Here's the answer:

Liquid penetrant testing is one of several methods used in nondestructive testing to locate discontinuities. You learned in "Introduction to Nondestructive Testing" that a discontinuity is a break in the continuity of, for example, a metal structure. You've seen such examples as: cracks, forging laps, folds, seams, inclusions, and porosity. In short, a discontinuity was seen to be a blemish! Liquid penetrant testing is simply a method used to find these blemishes.

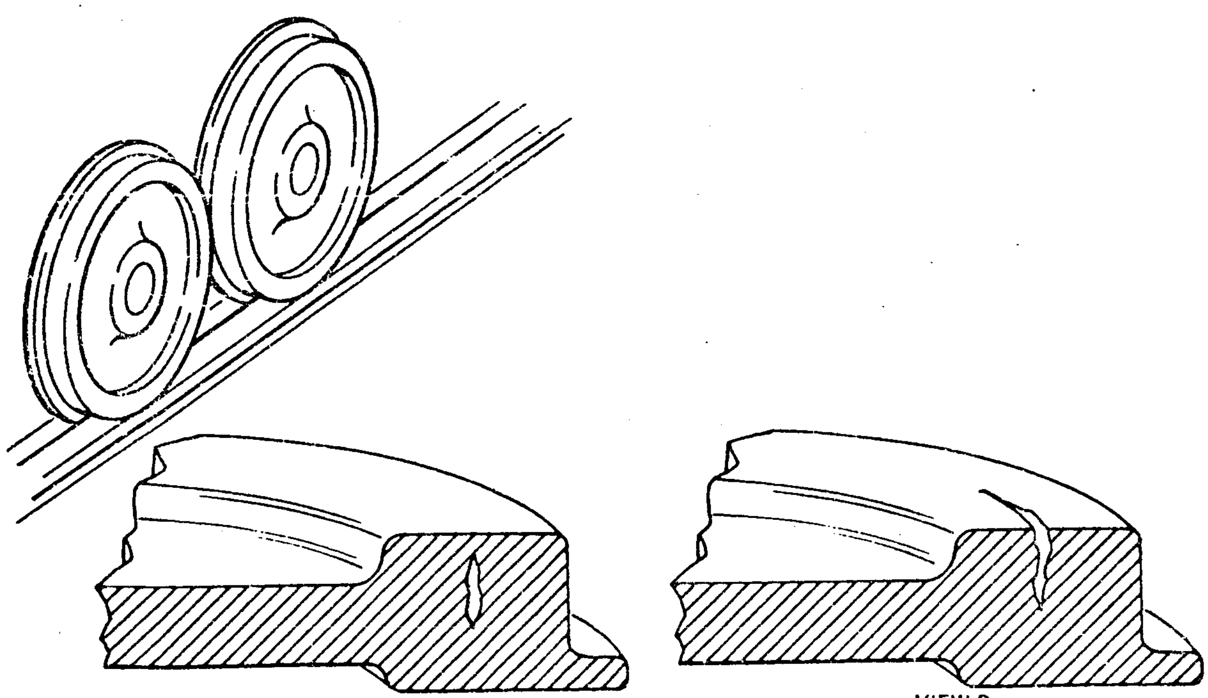
Liquid penetrant testing can be used on any material, except those considered "extremely" porous. Here's how the liquid penetrant method works. A dye carrying liquid is spread over the article to be tested. Time is then allowed for the liquid to "penetrate" discontinuities. That gets the dye down into them. Then the penetrant is cleaned from the surface of the article and a covering of powder is applied to the surface. The powder draws the dye that remains in the discontinuity back to the surface to give a vivid indication of the discontinuity that is easily visible to the human eye. Greatly over-simplified? Of course, but that's basically all there is to liquid penetrant testing. Since we're going to be required to use this method, however, we'll have to tackle the subject in a good deal more detail. So, let's get at it.

Turn to page 1-2.

From page 1-1

<u>A liquid penetrant inspection is one of several methods used in nondestructive testing to locate discontinuities</u>. It is important to note right now, however, that liquid penetrant testing will find only those discontinuities which are <u>open to the surface</u>! When you think about this testing method for a second or two, you can see that a simple point is mighty important. Let's take a moment right now and make dead certain we're all in step here — right at the start of this parade.

The gantry wheels below are used as typical specimens. Each has been cut to reveal a cross-section of the inside of each wheel. Each has an exaggerated and enlarged discontinuity — but only one of these discontinuities would be detectable with the liquid penetrant test before the cross-section was cut. Which view has the discontinuity that you could find with liquid penetrant test?



VIEW A (CROSS-SECTION)

VIEW B (CROSS-SECTION)

VIEW A. . . . . Page 1-4

VIEW B. . . . . Page 1-3

From page 1-2

Good! You've spotted the picture of the surface discontinuity (View B). This program will show you how a surface discontinuity such as this one is located with a liquid penetrant test.

As we take a close look at liquid penetrant testing, you will learn to answer easily such questions as:

WHAT CAN BE LEARNED FROM A LIQUID PENETRANT TEST?

HOW DOES LIQUID PENETRANT TESTING WORK?

WHAT MATERIALS ARE REQUIRED FOR LIQUID PENETRANT TEST?

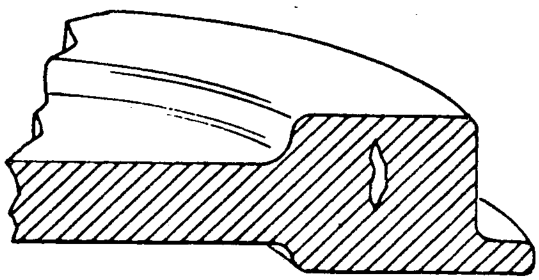
WHAT ARE THE LIMITATIONS OF LIQUID PENETRANT TESTING?

In fact, we've already begun to provide the answer to the first of these questions! Which one of the following re-states our partial answer?

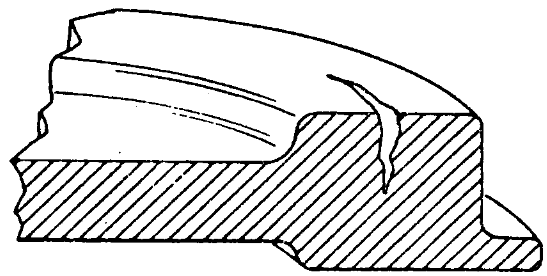
By using liquid penetrants, I can locate discontinuities which are open to the surface . . . . Page 1-6

By using liquid penetrant, I can locate all discontinuities . . . . Page 1-5

Another look at the two pictures is in order.



VIEW A
(CROSS-SECTION)



VIEW B
(CROSS-SECTION)

Although View A has a discontinuity, this discontinuity is not open to the surface and therefore can not be reached by a liquid penetrant.

The very first point to remember in this program is this: You can expect to learn the location of only those discontinuities which are open to the surface when you use the liquid penetrant testing method. View A couldn't be the answer since a liquid cannot reach the discontinuity, but look again at View B. That discontinuity could be reached with our liquid penetrant, couldn't it? View B is the correct choice, right?

Turn to page 1-3.

From page 1-3

We'll have to make that a little clearer. To be able to locate discontinuities by liquid penetrant testing, the discontinuities have to be open to the surface. If there is a discontinuity present but it does not have a surface opening, the penetrant cannot enter and the test will accomplish nothing.

Turn to page 1-6 and continue.

From page 1-3

Right! When you use the liquid penetrant test, you can find only those discontinuities which are open to the surface. By now you are well aware that there are many, many types of discontinuities. And many of them are, or can be made, open to the surface. Here's a list of a few of the discontinuities you met in the first programmed text in this series:

non-metallic inclusions	forging bursts, or cracks
porosity	cold shuts
stringers	shrink cracks
seams	blow holes
forging laps	grinding cracks
heat treat cracks	fatigue cracks

And when welding . . . .

crater cracks	porosity
shrink cracks	non-metallic inclusions

The question is - which of them could be detected with liquid penetrant testing?

Turn to the next page.

From page 1-6

Some discontinuities formed during rolling, forging, or casting are always open to the surface. They would be detectable with penetrants from the time they are formed. Forging laps, grinding cracks, and crater cracks are examples of this type of discontinuity.

Some of the others, however, are not always open to the surface. Examples of this type of discontinuity are non-metallic inclusions, stringers, and porosity. Non-metallics, for example, are formed when the ingot is poured. They could very well be sub-surface in the ingot and even if the entire surface of the ingot was subjected to liquid penetrant tests, no indications of the non-metallics would be found. The ingot is then cropped. The top of the ingot is removed, and a billet is formed. Would the non-metallics now be detectable? If the cropping cut through them, those exposed by the cut . . . or "brought to the surface" by the cut, could be located with penetrants; those still deep within the billet would not yet, however, be detectable with this method.

During rolling, forging, or casting (the next operation) the same possibility exists. If the operation brought discontinuities to the surface, a subsequent penetrant test would reveal their presence. And, to carry the example one step further, sub-surface discontinuities might yet be exposed during finishing operations such as grinding or machining. A liquid penetrant test conducted after the grinding or machining could then reveal the presence of a discontinuity hidden from it during earlier tests.

I would like to know more about the development of discontinuities during the processing of metals . . . . Page 1-9

I understand why discontinuities that are sub-surface at one stage in production could be open to the surface at another and am ready to continue . . . . . Page 1-8

From page 1-7

Fine, let's continue. Discontinuities that are sub-surface at one stage in production could be open to the surface at another. When they are, they're detectable with liquid penetrant inspection. Our first question was, "WHAT CAN BE LEARNED FROM LIQUID PENETRANT TESTING?" We now have the answer: We can learn the location of all discontinuities that are open to the surface at the time we apply our penetrants.

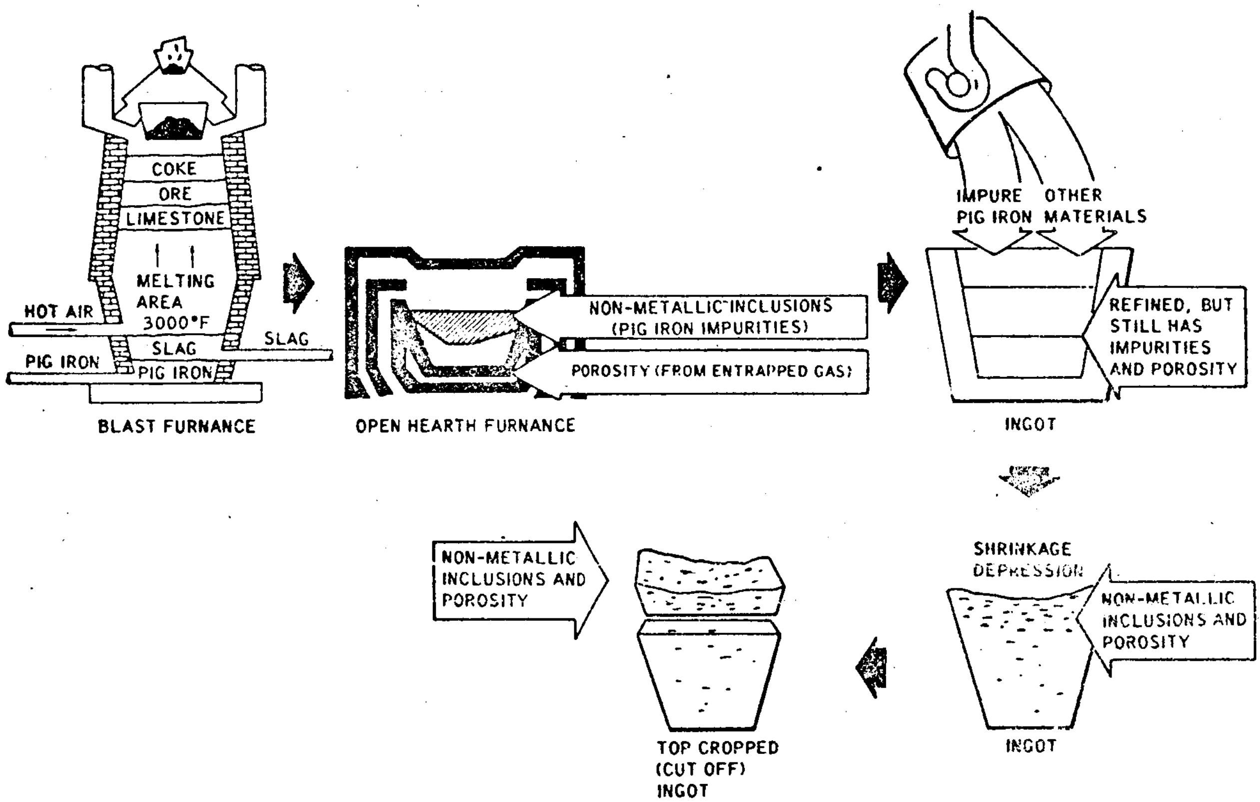
Let's turn to the second question, "HOW DOES A LIQUID PENETRANT TEST WORK?"

The answer to that one can best be seen in a brief look at the "Oil and Whiting" method — granddaddy of modern penetrant testing. The Oil and Whiting method was used for testing railroad parts, such as axles and couplings, about thirty years ago. It worked like this. First, the surface was prepared for the test by removing as much dirt, grease, rust and scale, etc. as possible. Then the part was soaked in kerosene long enough for kerosene to enter any discontinuities which were open to the surface.

In this method, kerosene served as the "penetrant."

Please turn to page 1-14.

Good for you. Let's consider again the steel making process as presented in the first programmed text in this series. Here are the first few steps taken in the process as shown in the flow chart from that book.

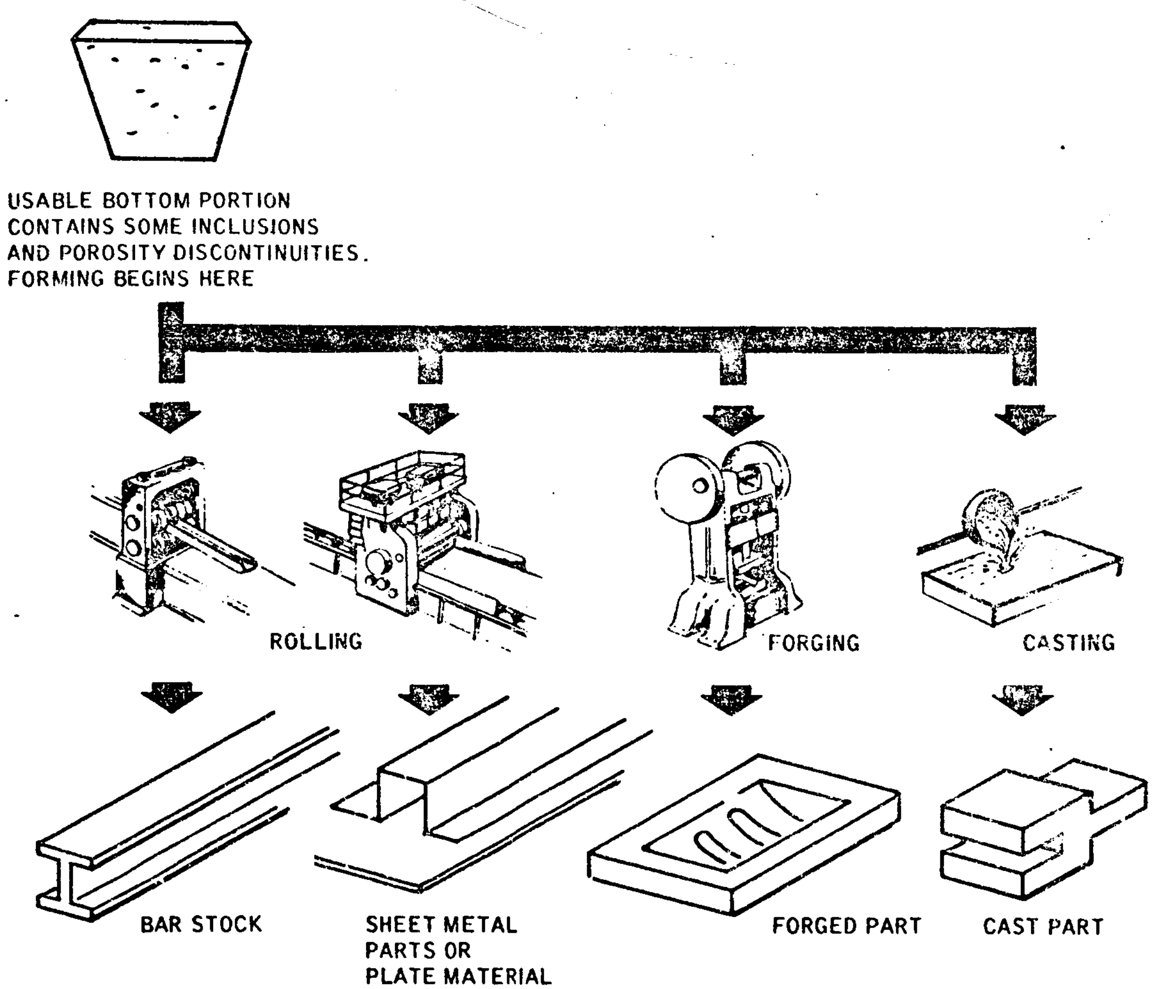


Although thus far in the steel making process only a few of the many possible discontinuities could have been created, those that the process has brought to the surface could be examined with liquid penetrants. Thus, if ingot cropping cuts through an area of porosity or non-metallic inclusions, examination of the cropped ingot with a liquid penetrant test would reveal the location of those discontinuities.

Turn to the next page.

From page 1-9

As the steel-making process becomes a production process, the flow chart shows that additional types of discontinuities (such as stringers, seams, forging laps, and cold shuts) can be created by rolling, forging, or casting.

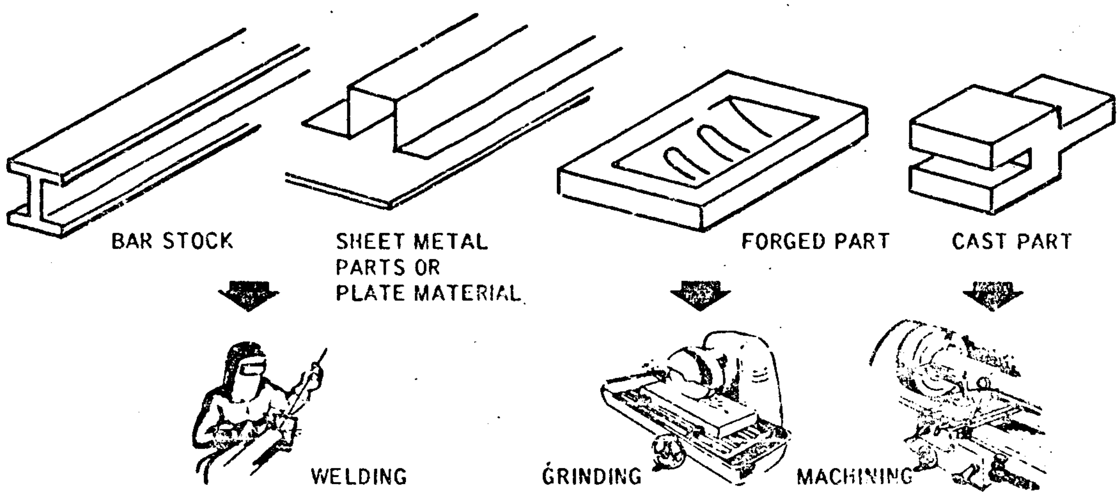


Discontinuities created by forming of metals are called "formed discontinuities" and many are always open to the surface. They, and any other discontinuities which have been opened to the surface during the production process, are detectable with liquid penetrants.

Turn to the next page.

From page 1-10

Now let's carry the flow chart one step further to show a later stage in development that can reveal discontinuities which may be found with liquid penetrant testing. That stage is the "finishing" stage where the materials developed from rolling, forging, and casting are further worked to form finished products. The finishing stage may include welding, grinding, and machining.

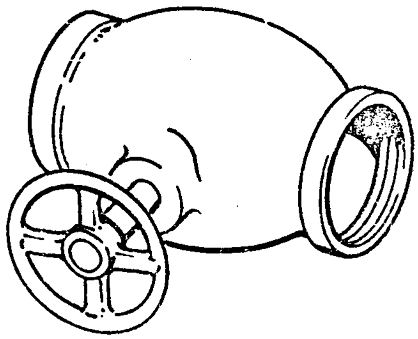


Two examples of new discontinuities which may develop during finishing operations are grinding cracks and crater cracks. The finishing stage may also expose sub-surface discontinuities, such as non-metallic inclusions, which can now be located by liquid penetrant testing.

Turn to the next page.

From page 1-11

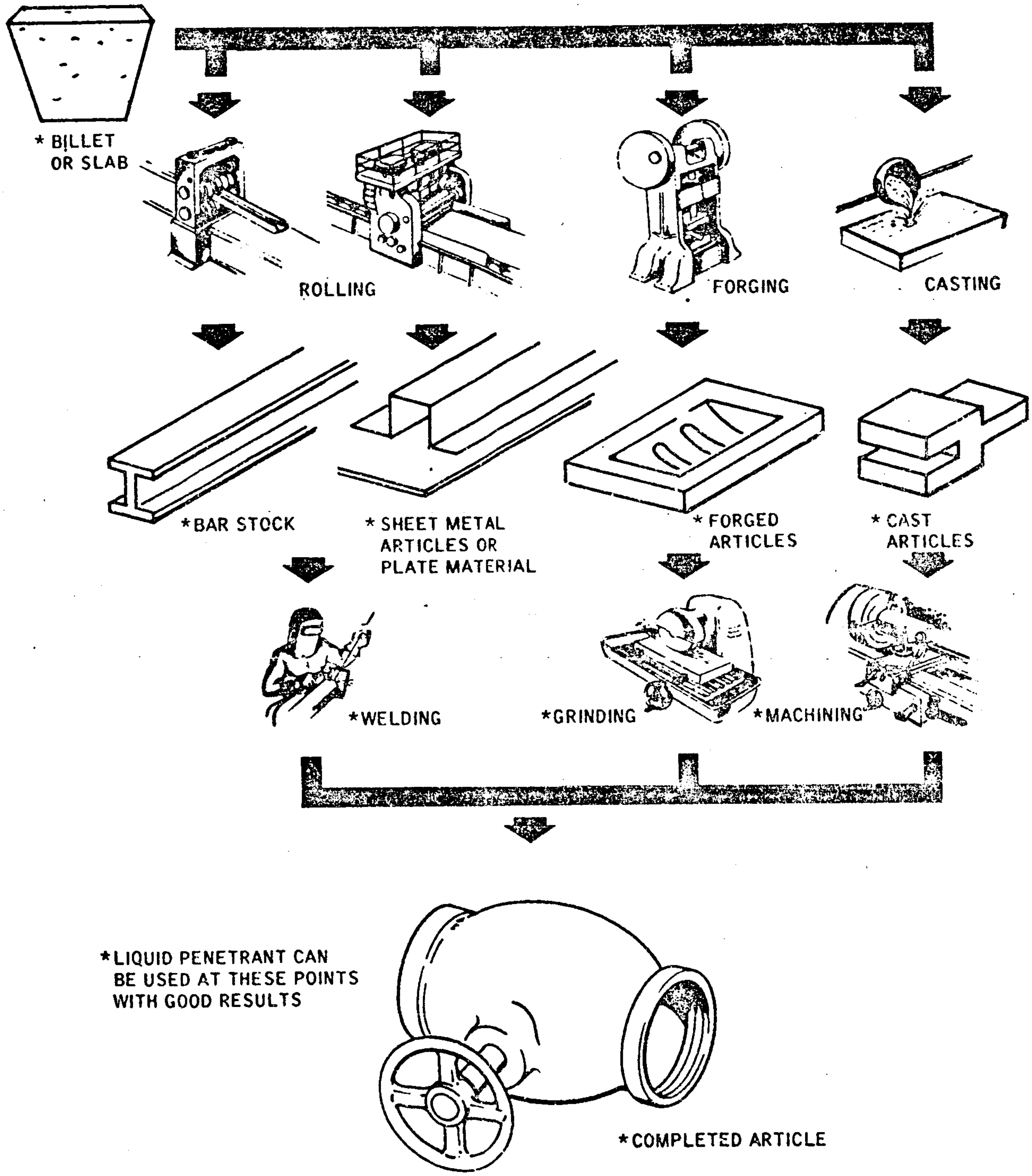
It is possible to expand the flow chart one step further and include the one other time that liquid penetrants can be used to locate discontinuities that would not have been detectable in the various stages we've discussed so far. This final stage occurs long after. steel making, forming, and finishing. It occurs during operational use of the article. Fatigue cracks are a good example of this type discontinuity. Such discontinuities may occur, (1) as the article is weakened through repeated use, and (2) as the result of overloading. The inspection will occur at some pre-determined time during the operational use of the article or when there is reason to suspect the article has been damaged. Liquid penetrant testing of large valve bodies on a periodic basis would be an example of the former, while testing of the same valve after an extreme system pressure would illustrate the latter.



During these periodic maintenance inspections, often previously sub-surface discontinuities as well as operational created discontinuities, might now be open to the surface and could be located with penetrants. (Fatigue cracks are sometimes traceable to subsurface discontinuuities that have weakened the article during its use.) Adding the example used here to illustrate this point, the flow chart will now give us the over-all picture and show us when we can expect liquid penetrant evidence of various discontinuties. This has been done on the following page.

Turn to the next page.

From page 1-12



In summary, a discontinuity that is not detectable with liquid penetrants in early production stages, could be detected with liquid penetrants at later stages.

Turn to page 1-8 and continue.

The article was then removed from the penetrant and the penetrant remaining on the surface was wiped away. (After this action, the only penetrant remaining was that which had entered discontinuities!) A thin coat of white powder was then applied to the entire surface.

This white powder served as a "developer." Soon, if there were discontinuities, the penetrant in them was drawn to the surface by the developer. The penetrant from the discontinuity changed the color of the developer above and surrounding the discontinuity, and in that way a visible image of the discontinuity was formed on the surface.

You've been given a glimpse of how a liquid penetrant test works in a brief history of the method's early days. Before we leave the subject, let's have a quick review.

Turn to the next page.

From page 1-14

1. The next few pages are different from the ones which you have been reading. There are ________ arrows on this entire page. (Write in the correct number of arrows.) Do not read the frames below. FOLLOW THE ARROW and turn to the TOP of the next page. There you will find the correct word for the blank line above.

5. open

6. Since they are ______________ to the ______________, crater cracks (can) (cannot) ______________ be located by liquid penetrant inspection.

10. liquid penetrant

11. Even after production is completed on an article and the article is in use, d______________ may develop.

15. developer

16. The Oil and Whiting method, though it was pretty simple, set the stage for modern liquid penetrant testing. We still use a p__________ and a d__________ in liquid penetrant testing.

This is the answer to the blank in Frame number 1.

1. four Frame 2 is next

2. These sections will provide a review of the material you have covered to this point. There will be one or more blanks in each f__________.

Turn to the next page. Follow the arrow.

6. open, surface, can

7. Crater cracks are a type of "formed" discontinuity that will always be __________ to the __________.

11. discontinuities

12. An example of a post-production discontinuity is a fatigue crack. If __________ to the __________ it can be detected with liquid penetrant testing.

16. penetrant
developer

17. However, there is a little more to it today. Today there are Six Basic Steps in accomplishing a liquid penetrant test. We'll now study each of them in detail.

Turn to page 2-1.

2. frame

3. By following the arrows or instructions you will be directed to the section which follows in sequence. Each section presents information and requires the filling in of ______________________________ .

7. open, surface

8. There are other types of discontinuities, such as porosity and non-metallic inclusions which may not always be detected by liquid penetrant testing. When they can not be detected, they will be sub-____________________ discontinuities.

12. open, surface

13. One of the early liquid penetrant testing methods which would locate fatigue cracks was used on railroad parts. It was called the ______________ and ______________________________ method.

Disregard this frame. The instructions are to turn to page 2-1.

9869-10

3. blanks (spaces, words)

4. Liquid penetrant testing is one of several nondestructive testing methods used to locate di________________.

8. surface

9. However, if they are open to the surface, discontinuities such as non-m__________ inc____________ can be located with liquid penetrant testing.

13. Oil, Whiting

14. In the Oil and Whiting liquid penetrant method, kerosene was used as the p________________.

4. discontinuities

5. It is important to note that liquid penetrant testing will locate only those discontinuities that are o________ to the surface.

Return to page 1-15, frame 6.

9. non-metallic inclusions

10. In many cases, a discontinuity which is sub-surface in an early stage of production will be exposed in a later production stage. It may then be detected by____________ __________ testing.

Return to page 1-15, frame 11.

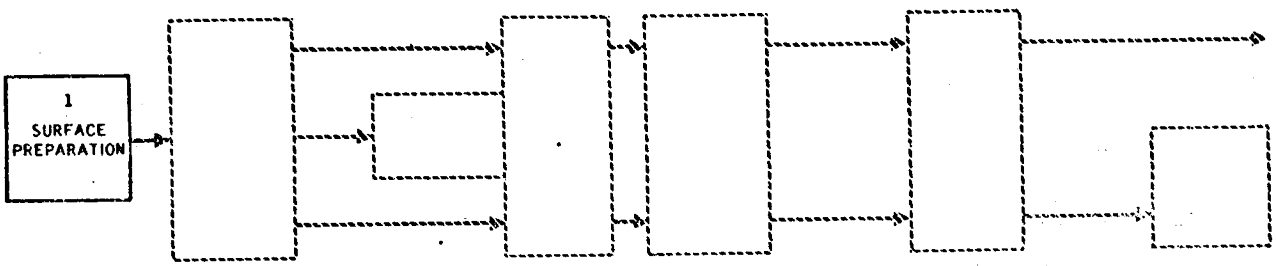
14. penetrant

15. After the kerosene had been allowed to penetrate any discontinuities, the excess was wiped away and a dry, white powder was applied. This powder was the dev____________ .

Return to page 1-15, frame 16.

CHAPTER 2 - SURFACE PREPARATION.

We are about to take the first of the Six Steps required in liquid penetrant testing. It is necessary that the sequence of the steps be learned. To help you in this learning, we will not only explain each step, but will also show each step on a flow diagram. As each step is introduced, it will be added to the flow diagram in solid lines. Here is Step One entered on the flow diagram.



Turn to the next page.

Step One is Surface Preparation

To be adequately prepared for any liquid penetrant test, anything that could block the penetrant from entering discontinuities must be removed. Right away this should bring CLEANING to mind. You can readily imagine how dirt and grease could block liquid penetrant entry to surface discontinuities. Both dirt and grease are called "contaminants" and they must be cleaned away in Step One. The list of contaminants would also include rust, scale, acids, and chromates — to mention just a few. Even water is considered a contaminant and must be removed in Step One — Surface Preparation.

It will also be apparent that such coverings as paint and metallic platings would also block penetrant entry. In most cases penetrant inspectors will be required to conduct their tests before any such coverings are applied. But not always. When such a covering is encountered, adequate surface preparation requires that it be removed before any further action is taken.

Therefore, if you received a finished article that had been painted, and you are required to give it a liquid penetrant test, your first action would be to . . . .

. . . . apply a penetrant carefully over the surface . . . . Page 2-3

. . . . remove the paint . . . . Page 2-4

. . . . thoroughly wash the article . . . . Page 2-5

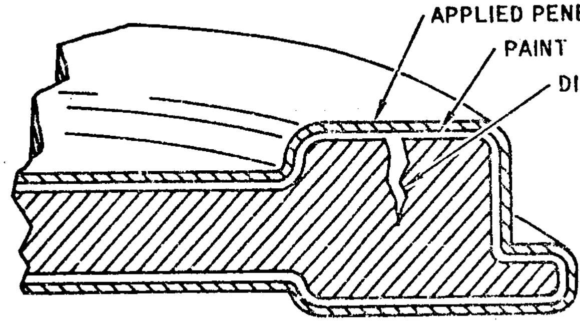
From page 2-2

"Apply a penetrant carefully over the surface". . . . ???? Hold on a minute! You're way ahead of time with that action.

Think over the basic principle of liquid penetrant testing again —

"A penetrant must enter the discontinuity."

Here's a picture of the procedure you've chosen . . . .



CROSS-SECTION

See our point?

Return to page 2-2 and pick an answer that will give our penetrant a chance to go to work!

5000-70

From page 2-2

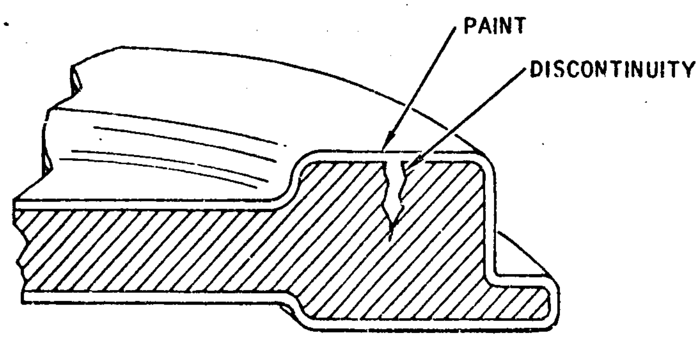
Right you are!

Before you took any other action (such as washing or cleaning) that paint would have to go. The same is true for metallic plating. Such plating is usually removed by a chemical process called "stripping." It is often a delicate operation, and, in the hands of a novice, could cause damage to the article. No attempt will be made here to teach "stripping" methods in this program, but remember this point: You must be down to the bare metal if you plan to use liquid penetrants on metals; you must be down to bare ceramic if testing ceramic articles; and the same goes for glass items. You are ready to really get down to work only when you have a bare surface. You can then start to CLEAN the surface and remove any contaminants.

Turn to page 2-6.

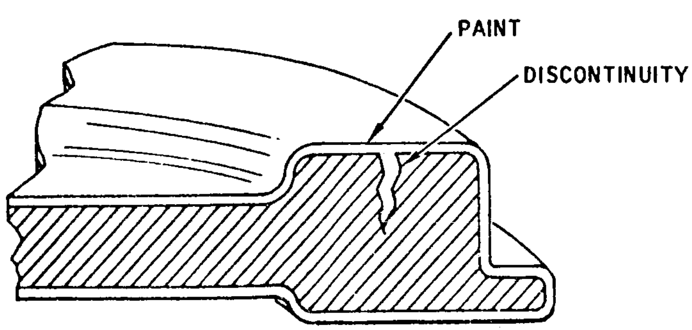
From page 2-2

"Thoroughly wash the article" was your choice. It's not correct. Why? Here's the article before washing.



CROSS-SECTION

Here's the article after washing.



CROSS-SECTION

See, no change! Penetrant still couldn't enter the discontinuity.

Return to page 2-2 and select another answer.

There are many possible ways to clean a surface, but the way you must do the cleaning will be found in Standards or Specifications to which you work. In industry today you will find that a cleaning solvent is generally required. The cleaner used must be capable of dissolving and flushing away the typical oils and greases often found on metal components. These two contaminants (oil and grease) are penetrants themselves and would certainly block the entrance of the test penetrant. Also, the cleaner must be volatile (readily vaporized) so that it easily evaporates out of tight discontinuities and does not remain to dilute or prevent the entrance of the penetrant. Naturally the cleaner must be free of contaminants and leave a minimum residue. Typical suitable materials for the job are acetone, perchloroethylene, isopropyl alcohol, and methylene chloride, all of which evaporate readily at normal temperatures.

But, here's a word of CAUTION!

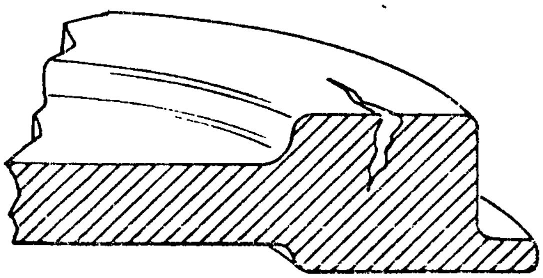
> Most solvent cleaners are toxic! Most of them are flammable! They burn.

This means they could cause injury or sickness to you. Avoid breathing their fumes for long periods. Avoid skin contact with them, and never smoke while handling them!

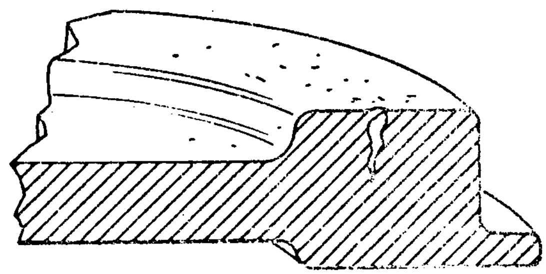
Turn to the next page.

From page 2-6

Any method that will not harm the surface of the article can be used to remove contaminants or surface coatings. However, this is strictly controlled by process specifications. Shot and sandblasting, for example, are not generally recommended, but there are times when they must be used. When they are, the risk is run that a discontinuity, otherwise open to the surface, might be closed. This is shown in the simplified illustration below:



CROSS-SECTION
BEFORE
SANDBLASTING



CROSS-SECTION
AFTER
SANDBLASTING

When shot- and sandblasting must be used, the discontinuities can be reopened with a chemical etching process that removes a very slight amount of material from the surface.

Which of the statements below best restates the possible danger from using methods such as sandblasting, without the extra chemical etching afterwards.

The discontinuities might be closed . . . . Page 2-8

Contaminants might be sealed in the discontinuities . . . . Page 2-9

A contaminant, such as shot or sand, might be forced into the discontinuity . . . . Page 2-10

From page 2-7

Right. Discontinuities might be closed with cleaning methods such as sandblasting or shotblasting.

When used, these harsh cleaning methods must be followed by a chemical process called "etching" that will actually eat away some of the surface to reopen discontinuities. This can be an extremely delicate operation and usually does not involve the liquid penetrant tester.

The penetrant tester will generally start with a surface that is not covered with any sort of plating or paint. He will apply the proper cleaning solvent with dampened rags, a brush, or use cleaning solvent with a vapor degreaser.

Contaminants such as dirt, grease, oil, acids, chromates, scale, rust, and water must be removed. This is essential for reliable liquid penetrant test. Acids and water may weaken or dilute the penetrant and render it useless. Grease, dirt, and paint may prevent the penetrant from entering discontinuities.

If the tester finds that the test specimen is contaminated by a material that is not removable by the volatile cleaners, other cleaning methods may be required. Remember, bare metal is the surface you want to test. However, IT IS ESSENTIAL THAT THE FINAL CLEANING OF A PART BE DONE WITH VOLATILE CLEANER AND THAT NONE OF THE PREVIOUS CLEANERS ARE PERMITTED TO LODGE IN THE DISCONTINUITIES.

Proper cleaning is the key to Step One — Surface Preparation. Before we proceed to Step Two, turn to page 2-11 and check yourself on the major points with a short review.

From page 2-7

Your answer: "Contaminants might be sealed in the discontinuities" if cleaning is done with sandblasting or shotblasting. And you're right, they may. But, that's not the real damage from such cleaning. It's more basic! We don't care what contaminants are sealed in the discontinuities because if the discontinuities are not open to the surface, we can't get a penetrant into them in the first place! It's the sealing itself that is really damaging to our liquid penetrant effort. And it can result when cleaning is attempted with either sandblasting or shotblasting.

Return to page 2-7, take a look at the pictures again, and then choose the simple, basic statement that re-states the real damage caused by those two taboo cleaning methods.

Well now, you've answered that the harm from cleaning by sandblasting or shotblasting would be that a contaminant such as shot or sand will be forced into the discontinuities.

This is not the best answer on page 2-7 because, although it is possible, it isn't likely to occur. Shot will very likely be too large and therefore useless to clean out discontinuities in the first place! Sand that is blown into small discontinuities is apt to be blown out too. We are worried over the possibilities of closing discontinuities that would otherwise be open to be reached with liquid penetrants.

Why not return to page 2-7, look it over again, and choose once more when you're ready?

From page 2-8

1. Step One in any liquid penetrant testing is Surface ____________________.

3. contaminants

4. Water, grease, oil, scale, and rust are all considered ________________.

6. discontinuities

7. Sandblasting, shotblasting, wire brushing, emery cloths, and metal scraping are not generally recommended because they all might ______________ a discontinuity that might otherwise be open to the surface.

9. close
   contaminants

10. A vapor-degreaser uses one of these solvent cleaners called trichloroethylene which, like most of the other solvent cleaners, is both toxic and f__________ble.

1. Preparation

2. During Step One, any contaminants that might block ____________ entry into any discontinuities must be removed.

4. contaminants

5. Although metallic platings themselves are not considered contaminants, they must be removed prior to any cleaning. They are removed by a process called s________________.

7. close
(cover, conceal)

8. When these harsher methods are allowed, they must be followed by a chemical etching process, sometimes called "pickling," that will re-open any ________________ that may have been closed.

10. flammable

11. Because these solvents will explode and burn you may not ______________ while handling them.

2. penetrant

3. Step One involves two considerations. First, any metallic plating must be removed. Second, all con____________(s) must be removed with proper cleaning.

Return to page 2-11, frame 4.

5. stripping

6. If a metallic plating were not removed, the penetrant inspection results could be thought to indicate mistakenly that the part is free from ____________ies.

Return to page 2-11, frame 7.

8. discontinuities

9. Unlike sandblasting and wire brushing, solvent cleaners will not ____________ discontinuities and are widely used to remove ____________(s) such as rust, scale, and grease.

Return to page 2-11, frame 10.

11. smoke

12. Because these solvents are toxic you should avoid breathing their fumes and avoid skin contact with them.

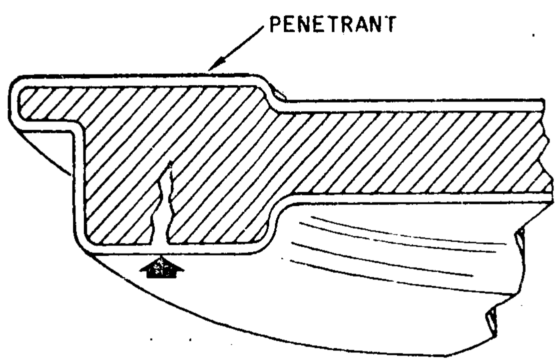
Turn to the next page.

CHAPTER 3 — PENETRANT APPLICATION.

Penetrant application is step 2 in the procedure. What materials are required in this step? A penetrant, naturally. But, what will do that job?

Basically, any liquid could be considered a penetrant. The so called "penetrating power" is gained from a force in nature called "capillary action." This force is available to any liquid. Capillary action is the force that causes sap to rise in trees. The "penetrant" is the sap. Capillary action is the force that causes oil to rise in a lamp-wick, a towel to soak up water, and a blotter to clean up spilled ink. The "penetrants" were: oil, water, and ink, respectively.

The liquid penetrant placed on a surface during an inspection does not merely seep into discontinuities, it is pulled into them by capillary action. Remember penetrant does not depend upon gravity. Capillary action is the reason you can cover the under surface of an item with a penetrant and have it work its way upward into a discontinuity while working against gravity.



CROSS-SECTION

Turn to page 3-2.

From page 3-1

For liquid penetrant testing, however, we require a great deal more from our "penetrants" than the ability to capitalize upon nature's gift, Capillary Action. Today even the kerosene oil used as a penetrant in the Oil and Whiting method is considered crude and outmoded. Although most penetrants used today are still either oil or water based, chemists have been working with them until they seem to have combined the un-combinable.

The penetrant must have "fluidity" — so it will penetrate the smallest discontinuities and drain well. The penetrant must have "body" (the exact opposite of fluidity) because it must have the body to stay on the surface during its application. A certain amount of volatility is desired because it aids a penetrant's brilliance. And, of course, it must have the right combination of viscosity and wetability. However, the proper combination of chemicals is, fortunately, done for us! We need not learn the chemistry involved. What this all means to us, as testers, is that a penetrant today must have five abilities or properties to help us.

Turn to the next page.

From page 3-2

Here are the five abilities, or properties, that today's penetrants must have to help us — as testers.

1. The ability to hold a dye material in suspension.
2. The ability to spread the dye evenly over the surface.
3. The ability to carry the dye into any discontinuity open to the surface.
4. The ability to bring up the dye as it is "coaxed" back to the surface.
5. The ability, when desired, to be easily removed.

Look back over the first four properties again; notice they all do something with a dye. The dye's the thing!

Turn to the next page.

From page 3-3

New penetrants and the addition of dyes have given us the liquid penetrant methods used today. There are two dyes used:

FLUORESCENT	AN ALMOST COLORLESS DYE WHICH EMITS VISIBLE LIGHT RAYS WHEN REVIEWED UNDER BLACK LIGHT.
NON-FLUORESCENT OR VISIBLE	A BRILLIANTLY COLORED DYE THAT IS HIGHLY VISIBLE UNDER NORMAL LIGHTING CONDITIONS. THIS TYPE OF DYE IS NORMALLY CALLED VISIBLE DYE.

When either a fluorescent or non-fluorescent type of dye is combined with a suitable liquid, a dye-penetrant solution is formed.

Liquid penetrant testing requires, as Step Two, the spreading of one of these dye-penetrants over the surface to be inspected. We rely upon a natural force to get the dye-penetrant into discontinuities. That force is called . . . .

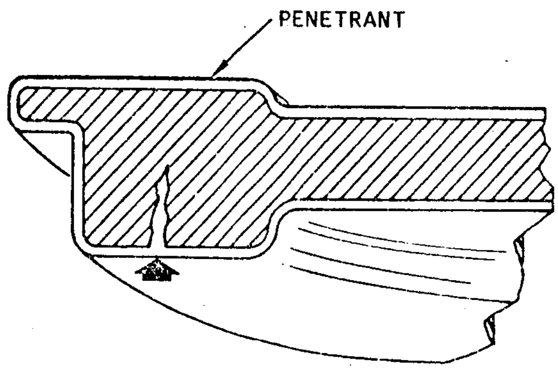
. . . . gravity . . . . Page 3-5

. . . . capillary action . . . . Page 3-6

From page 3-4

Ooops! Hold on a minute.

We don't count on gravity to get the dye into a discontinuity. We often work on the under surfaces during penetrant application. Gravity certainly wouldn't help then, would it? Remember this picture?



CROSS-SECTION

In order for the dye penetrant to fill the discontinuity it had to be drawn up into the discontinuity against the downward pull of gravity. Capillary action can do this.

Turn to page 3-6.

From page 3-4

Right! We'll count upon capillary action to get our dye into the discontinuities. We had two types of dyes to work with — fluorescent and non-fluorescent. Here are their characteristics.

Fluorescent dyes are those that will be visible as a brilliant yellow-green glow when exposed to black light. Black light is a special light with wave lengths that fall between visible and ultraviolet and is not visible to human eyes. It is in no way injurious to humans. The inspection is conducted in a darkened area with black light the only illumination. It will make discontinuity indications actually glow in the dark for easy viewing and interpretation.

The name visible-dye is used to indicate a dye which contrasts sharply with its background in normal lighting (daylight, electric bulb). No darkened area is required when it is used. This dye is usually seen as a brilliant red against a chalk-white background (there are other color combinations for special purposes). These non-fluorescent contrast dyes are sometimes called "high-visibility," "color contrast" or "daylight-visible" dyes.

Visible-dye penetrants are not the most sensitive materials and suffer by comparison with fluorescent penetrants, which are more visible and thus more likely to be seen by the inspector. However, non-fluorescent penetrants do not require viewing in a special dark area illuminated with "blacklight."

Which of the following is correct?

Fluorescent dyes will produce red against white discontinuity indications . . . . Page 3-7

Visible dyes require the use of black light . . . . Page 3-8

Yellow-green fluorescent discontinuity indications will be seen only when exposed to black light . . . . Page 3-9

From page 3-6

Color-wise you should have selected another answer. Fluorescent dyes do produce a color, but the color is a brilliant YELLOW-GREEN and is only visible when exposed to black light. Visible dyes are the type that, in their commonest form, produce a red discontinuity image against a white background. Although there are other colors available for special purpose visible-dye penetrants, none are fluorescent, and they do not require black light. With this in mind, return to page 3-6 and select another answer.

From page 3-6

Since we evidently have not made this clear enough, we will pause here for a restatement of the characteristics of fluorescent and non-fluorescent dyes.

FLUORESCENT DYES

Fluorescence is the ability of a material to absorb light at one wave length and return it at another wave length. The black light consists of light with a wave length that is invisible to the human eye. The flourescent dyes absorb this wave length and emit light at a wave length that is visible to the human eye, usually of a brilliant yellow-green color.

VISIBLE DYES

These dyes will not be affected by use of a black light. They are non-fluorescent. Visible dyes have an ability which make them valuable in liquid penetrant testing — the ability to produce a bright color under <u>normal</u> (daylight or electric bulb) lighting. They are usually seen as bright red against a white background.

Remember, fluorescent dyes are seen under black light — visible dyes are seen <u>without</u> special lighting! On the basis of this, return to page 3-6 and select the correct answer.

From page 3-6

Correct.

Yellow-green fluorescent discontinuity indications will only be seen under black light because of the nature of the fluorescent dye.

Visible dye indications can be viewed in normal light. Hence their other names — "daylight visible," "color contrast," etc. Either of the two types of dye (fluorescent and visible), when combined with a suitable penetrant liquid, can be called a "dye-penetrant."

From the preceding information, determine whether the following statement is true or false.

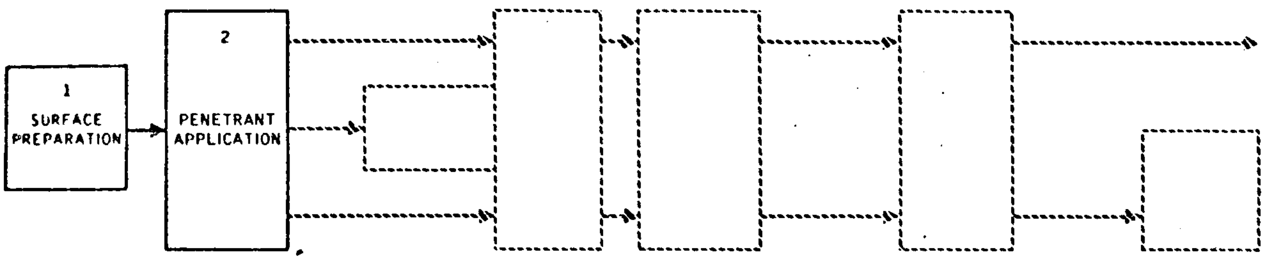
Both fluorescent dye-penetrant and visible dye-penetrant depend upon capillary action for penetration into a discontinuity.

True . . . . Page 3-10

False . . . . Page 3-11

From page 3-9

True! Both fluorescent and visible dye-penetrants depend upon capillary action for penetration into a discontinuity. That is, they do once we've applied them properly to the surface we want to examine. Then penetrant application is Step Two, and we're ready to add it to the flow diagram.



Dye penetrants, either fluorescent or visible, can be applied in the same ways. They can be applied by any one of the following means:

Dipping (or immersion)
Spraying
Brushing
Pouring

Regardless of which method is chosen, the area to be tested must be adequately covered. As <u>minimum</u> coverage you can keep these figures in mind.

1. Penetrant must cover at least one-half inch either side of a weldment.
2. Cover all <u>other</u> surfaces at least one full inch around the area to be tested.

Is the following statement true or false?

Applying a dye-penetrant under pressure, such as with a spray gun, is done because it will more effectively force the solution into small discontinuities than will dipping.

True . . . . Page 3-12
False . . . . Page 3-13

From page 3-9

You do not yet believe that both dyes depend on capillary action for penetration into a discontinuity? But, they do both depend equally upon capillary action. Let's see if we can convince you of this fact.

Penetrants (liquids) would have to depend on one of two actions to enter a discontinuity — gravity or capillary action. If gravity was the force upon which they depended, penetrants would seep into discontinuities only in a downward direction. Remember that penetrants will work their way into a discontinuity even from the underside of an article. Capillary action is the reason. Neither dye, fluorescent or visible, is restricted to the upper surfaces. Nor is one better for under surfaces!

We again ask the question — Do both fluorescent - and visible-dye penetrants depend on capillary action for penetration into a discontinuity? You bet.

Turn to page 3-10 and your answer is. . . .

You have said that applying dye-penetrant with pressure from a spray gun will more effectively force the solution into small discontinuities than will dipping of the article. While use of a spray gun (or spray can) is becoming more and more popular as a means to apply penetrants, it is not for this reason. The spray method has merely proved itself convenient in the application. The real work is accomplished by capillary action regardless of the method of penetrant application.

Turn to page 3-13.

From page 3-10

Good. With the dye-penetrant properly applied, sufficient time should be allowed for the penetrant to enter all the discontinuities, for capillary action to do its job. This time is called the penetration time or "dwell" time. How long a time is required? Fortunately, there are charts to help with that decision. The penetrant manufacturers provide us with penetration time charts for all of the various penetrants they produce. They suggest the minimum times that should be used. Remember that point. The penetration time charts suggest minimum times. Here is a fictitious time chart, for a fictitious penetrant we will call Aphrodite Corporation's penetrant P-18-A.

APHRODITE CORPORATION P - 18 - A

MATERIAL	TYPE OF DISCONTINUITY	PENETRATION TIME
STAINLESS STEEL	SEAMS POROSITY CRACKS	10 MINUTES 5 MINUTES 2 MINUTES
ALUMINUM	SEAMS POROSITY CRACKS	5 MINUTES 3 MINUTES 2 MINUTES
PLASTIC	POROSITY CRACKS	5 MINUTES 3 MINUTES

What do the times on the above chart represent?

The maximum time penetrant can remain on an article for good test results . . . . Page 3-14

The time an article must remain submerged in a penetrant tank . . . . . . Page 3-15

The minimum time necessary for a penetrant to enter a discontinuity . . Page 3-16

From page 3-13

Hold on a minute! The penetration times suggested on the charts aren't maximums, but minimums! They tell us the least time that can be used if we expect valid test results. These times should never be considered maximums. It would then be too easy to fall short of this time trying to avoid running overtime. The result? You would not use a time that was long enough to allow penetrant to enter all the discontinuities!

Return to page 3-13 and select another answer.

Your answer is not correct. Here's why.

Remember, dipping, or immersion, was just one of the four methods suggested for penetrant application. There was also pouring, spraying and brushing. The penetration time charts are equally useful when these methods are used. If this is so, the charts cannot suggest, as you have chosen: "The time an article must remain "dipped" in a penetrant tank." The dipping is momentary. It merely applies the penetrant. After you have re-examined the selections on page 3-13 you'll see that there is a much better answer.

Re-read page 3-13 and make another selection!

From page 3-13

Correct. The times suggested by the chart do reflect the minimum times allowable.

The basis for determining these minimum "dwell" times was a simple one. It just takes a penetrant longer to enter tiny tight discontinuities than it does to enter their larger cousins. Therefore, the type of discontinuity sought will affect the time selected. Take another look at the time chart we've dreamed up to illustrate this point.

APHRODITE CORPORATION P - 18 - A

MATERIAL	TYPE OF DISCONTINUITY	PENETRATION TIME
STAINLESS STEEL	SEAMS POROSITY CRACKS	10 MINUTES 5 MINUTES 2 MINUTES
ALUMINUM	SEAMS POROSITY CRACKS	5 MINUTES 3 MINUTES 2 MINUTES
PLASTIC	POROSITY CRACKS	5 MINUTES 3 MINUTES

Notice that a type of discontinuity is called out, and a different time is suggested for each of them. Thus the type of discontinuity sought becomes one of the variables in determining the dwell time used with any given penetrant. Another variable is also shown in the chart. Can you spot it?

The type of penetrant used . . . . Page 3-17

The type of material being examined . . . . Page 3-18

Your answer, "The type of penetrant used," does not pinpoint a variable. The whole chart applies to only the penetrant specified. This is not a variable. This chart will always be used for that specific penetrant.

Return to page 3-16, study the penetrant time chart again and select the correct response.

From page 3-16

Good for you. The two variables are type of material being examined and type of discontinuity for which you are testing.

There are instances in which you might be asked to look for all discontinuities of an article instead of just one type. There are a couple of ways that you may determine the penetration time when looking for all discontinuities. These methods are:

1. Use the penetration time chart.
2. Use a predetermined time as specified during design of the article.

Let's take a look at how the chart may be used to determine penetration time (or dwell time) when inspecting for <u>all</u> discontinuities with one test. Remembering the qualities of the chart we showed you (or referring back to it on page 3-13), which of the actions below would you take to determine penetration time for all possible types of discontinuities in any one article.

I would use an average time obtained by taking an average of the longest and shortest times on the chart . . . . Page 3-19

I would use the shortest recommended time to expedite the test . . . . . Page 3-20

I would use the longest suggested time to be on the safe side . . . . . . Page 3-21

You must have been guessing. If you take an average of the shortest and longest chart times and use this time to test for all possible discontinuities, you will not be reaching the required minimum time for some of them. Remember, if you are checking for all discontinuities, penetrant dwell time must be long enough to penetrate all of them. Think about it again and return to page 3-18 for another selection.

Wait just a minute. Consider again that the penetration times are the minimum times allowable. If you used the shortest time on the chart when asked to pick up all discontinuities, you would most certainly miss those needing the longer minimums.

Look over the selections on page 3-18 and select again.

From page 3-18

Very good. Be on the safe side. Use the longest suggested time. Since the times on the chart are minimums, this is the only way to be sure that the penetrant will reach discontinuities of all types.

Now let's take a look at the other method of obtaining penetration time for testing an article to find all discontinuities. This method requires the use of a predetermined time as specified during design of the article. This simply means that some of the time you will be told the penetration time. This time is determined by design and quality control engineers. The reason for this is that the men who design the article are best qualified to determine the quality level that is required for the article. They know what it is to be used for and can therefore determine what degree of quality must be achieved.

When the engineers determine the quality level, they also select a penetrant that will be sensitive enough to do the testing job. They choose one with the correct amount of "sensitivity."

It all boils down to this: (1) You obtain the penetration time from the chart that applies to the penetrant you are using; or (2) you use a predetermined penetration time which will be given to you.

Turn to the next page.

From page 3-21

There are a couple of other points to consider when using manufacturer's penetration time charts.

First, the minimum times recommended on the charts are based on the assumption that the penetrant will remain wet throughout the dwell time. This means that the penetrant must initially be applied liberally to the test surface. Also additional penetrant may have to be applied during the dwell time if it appears that the initial coat is drying. This will assure full penetration into discontinuities. If the dwell time exceeds 30 minutes, the penetrant will have to be reapplied to assure that the penetrant remains wet during the entire dwell time.

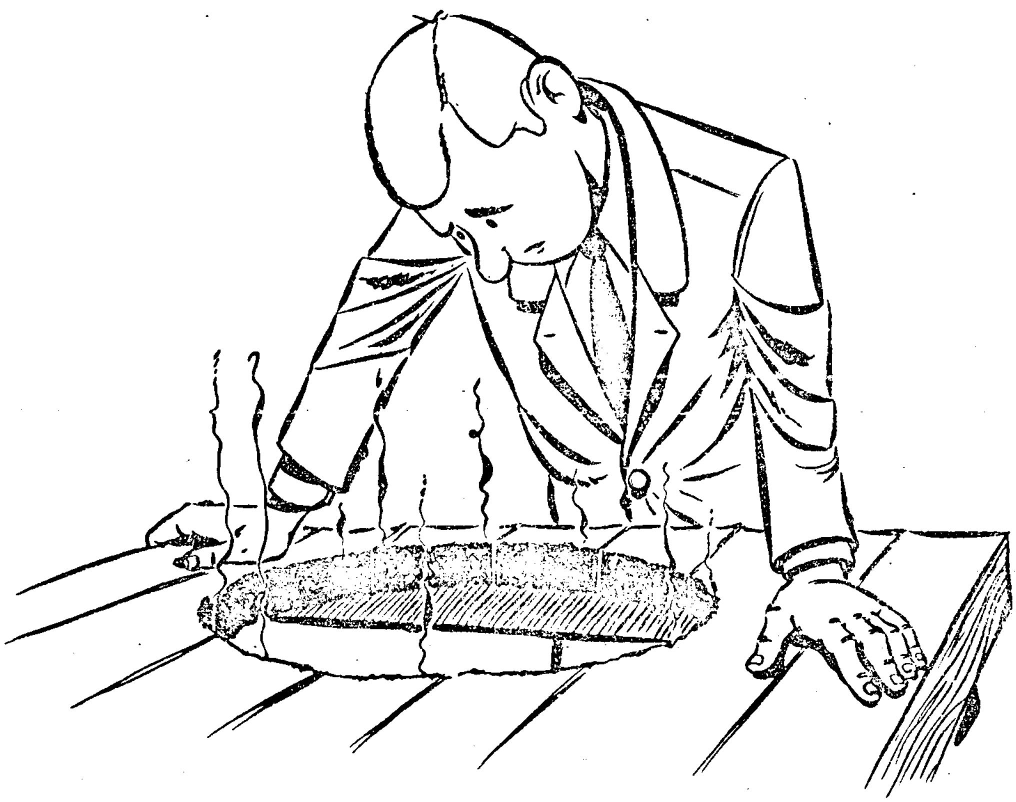
While there is no maximum penetration time recommended, the penetrant should be wet prior to starting the next step. Because of this, once the minimum dwell time is reached it is best to get right on with the rest of the procedure while the penetrant is still wet. We will talk more about this when we get into Step Three.

Turn to the next page for one final consideration to keep in mind when using the time charts.

From page 3-22

The final point to be noted concerning the time charts is that the charts are set up to be used in "normal" temperatures. By normal temperature we mean that the penetrant will be between 50°F and 100°F when it is applied and should remain within that range during the dwell time.

The upper limit does not present too much of a problem since articles become just too hot to handle when they are above 100°F.



Besides a few burnt fingers, the penetrant may become uselessly vaporized when applied to extremely hot articles.

Turn to the next page.

From page 3-23

The low temperature limit of 50°F presents a more serious problem. It may be common practice in some areas to apply penetrants outdoors at temperatures around freezing. Below 50°F, the penetrant becomes sluggish and its sensitivity is greatly reduced. The time charts become useless since they were based on a known sensitivity at normal temperatures. In extremely low temperatures the penetrant may become so sluggish that it will not enter discontinuities regardless of the time allowed.

For the charts to be useful under cold temperature conditions the penetrant must remain above 50°F for the duration of the dwell time. This may require heating of the penetrant and the article before application.

Which of the following is correct?

Normal penetrant temperatures must be above 50°F .... Page 3-25

Temperatures above 100°F will restrict penetrant entry............ Page 3-26

Penetrants will become useless below 50°F .... Page 3-27

From page 3-24

"Normal penetrant temperatures must be over 50°F" — correct.

You've now had a look at the first two steps involved in a liquid penetrant test. They were:

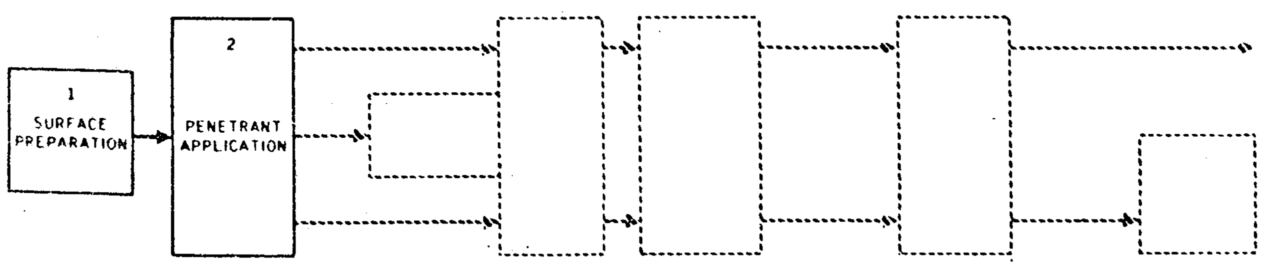
Step One, Surface Preparation.

Anything which would hinder entry of the penetrant was removed. Metallic plating was removed by stripping; contaminants by cleaning. Materials used ranged from rags to trichloroethylene and vapor degreasers.

Step Two, Penetrant Application.

In this step the article must be evenly covered; the penetrant must extend at least one inch on either side of the area to be tested (1/2 inch on either side of weldments); and enough time must be allowed for penetrant entry. Penetrants are applied by either dipping, spraying, brushing, or pouring. Two types of dye are used in penetrants.

Here's our flow diagram now:



Turn to page 3-28 for a brief review.

From page 3-24

Watch out now. This is a hot one! Penetrant temperatures above 100° F will not restrict penetrant entry but, these temperatures might cause the article to become heated. The heated article, in turn, could become hard to handle. Additionally, penetrants will lose some of their effectiveness if they are heated excessively. Their chemical consistency can be changed adversely. If you will now return to page 3-24, the correct answer will probably be obvious.

5000-80

From page 3-24

Your answer is not entirely correct.

This is true only in a sense. It would be more accurate to say that penetrant becomes sluggish, and test sensitivity is lessened, when the temperature falls below 50°F. Penetrant is not useless below this temperature (unless the penetrant is frozen, of course), but a penetrant temperature below 50°F is certainly not good in a test situation. It is possible that chilled penetrant would not enter tight cracks. Either the penetrant or the article should be heated so the penetrant will do its job as expected, and the time charts will be meaningful.

Take another look at page 3-24 and choose the statement which is entirely true.

From page 3-25

1. Step One in any Liquid Penetrant Test is __________ ______________.

   Step Two in any Liquid Penetrant Test is __________ ______________.

5. capillary
   action

6. Penetrants are commonly applied in any one of four ways.

   They can be br__________ on.

   They can be spr__________ on.

   They can be po__________ on.

   Or penetrant can be applied by__________________ the article in a tank of penetrant.

10. visible

11. These visible dyes usually appear as a brilliant red against a chalk white and can be seen without the aid of ____________ light.

15. discontinuity
    material

16. Recommended penetration or "dwell" times for these various conditions can be found in prepared charts. It must be remembered, however, that the times suggested are ________________, not maximums.

1. Surface Preparation

   Penetrant Application

2. Although, to some degree, any liquid can be considered a p____________,
   penetrants used in this nondestructive testing method must possess five abilities.
   The first four of these all do something with a d_________.

6. brushed
   sprayed
   poured
   dipping (or immersing)

7. The first four required properties of any penetrant all deal with its dye. In the words of this text, "The dye's the thing." Because of its importance, we have two types of dyes with which to work. They are:

   1. ____________________, and
   2. ________________________ .

11. black

12. When visible dyes are used, no special _______________ing is required and the inspection gains greater mobility.

16. minimums

17. Regardless of whether the penetrant is applied by b____________ing, s____________ing, or d___________ing, the penetrant must be no hotter than 100°F and no colder than ____________°F.

2. penetrant

   dye

3. Today a penetrant must have the ability to:
   1. Hold a ______________ material in suspension.
   2. Spread the ____________ evenly over the surface.
   3. Take the ____________ into any discontinuity open to the surface.
   4. Bring up the ____________ as it is "coaxed" back to the surface.

7. Fluorescent

   Visible-Dye

8. ________________________ dyes will be seen as a brilliant yellow-green glow under

   b______________ l______________ .

12. lighting

13. When penetrants are applied by spraying or brushing, care must be taken to insure that the article is adequately covered with penetrant. It is suggested that, as minimums, at least__________ inch either side of a weldment be covered and on other articles at least _____________ inch around the area to be inspected.

17. brushing
    spraying
    dipping
    50° F

18. If the penetrant is less than ___________ in temperature it will be too sluggish for reliable results and the prepared penetration time charts will be next to useless because they are based upon penetrant temperatures between _______° and

    ______________°F.

3. dye
dye
dye
dye

4. Additionally, the fifth desired ability, or property, will allow the penetrant to be easily removed when desired. When a penetrant possesses these five properties it can be put to work where it will gain its penetrating power from a force in nature called

_______________ _______________

8. Fluorescent
black light

9. Black light falls between visible light and ultra-violet light and (is) (is not) _______________ harmful to humans.

13. 1/2
one

14. After penetrant has been properly applied, it will be allowed to remain on the article for a period of time called the penetration or _______________ time.

18. 50°F
50°F and 100°F

19. With this review in mind, you are now ready for Step Three. Let's get to it. Please turn to page 4-1.

4. Capillary Action

5. The under surface of an article can be covered with a penetrant which will work itself up into any discontinuities because of the principle of __________ __________ .

Return to page 3-28, frame 6.

9. is not

10. Color-contrast, or high visibility are other names given to ______________ dyes.

Return to page 3-28, frame 11.

14. dwell

15. The length of time allowed will depend upon

1. The type of d__________ sought.
2. The kind of m______________ being examined.
3. The type of penetrant being used.

Return to page 3-28, frame 16.

Excess penetrant is that penetrant still on the surface of an article which has not entered a discontinuity during the penetration time. In Step Three we are going to remove this excess. (It is necessary that the excess penetrant be wet prior to starting this step. Therefore, if Step Three is delayed for any reason and the penetrant has dried, you may reapply the penetrant to the surface prior to starting Step Three.)

When removing excess penetrant, care must be taken not to do anything that may remove penetrant from discontinuities while removing the excess. This is one reason for having the penetrant wet prior to starting the removal required by Step Three. If you have already started removing excess before you notice that penetrant has dried on the surface, you can't just wet the penetrant with a new application. You must start over with recleaning the article. It is possible that you could have removed penetrant from discontinuities by starting with a dried surface. The same applies if you encounter delays in later steps of the procedure. If it is possible that penetrant may have been removed from discontinuities or may have dried up in the discontinuities, START OVER WITH STEP ONE.

Choose the correct statement.

Reclean the test specimen if you notice that the excess penetrant is dry before you start Step Three . . . . Page 4-2

Reclean the test specimen if you notice that the excess penetrant is dry after you have already started Step Three . . . . Page 4-3

From page 4-1

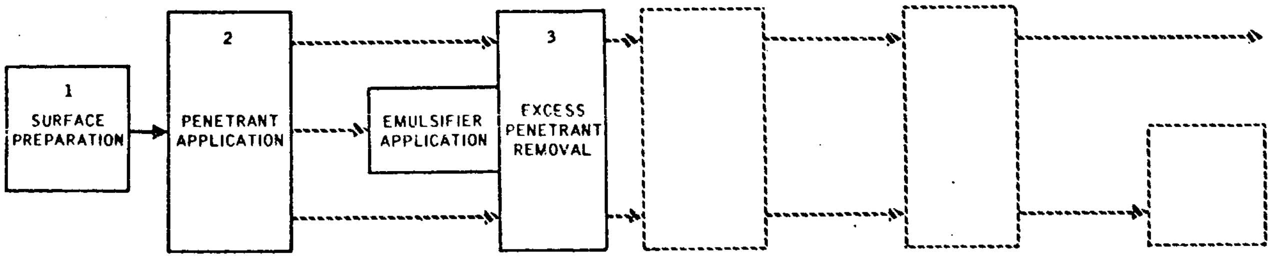
You answered that you would reclean the article if you notice that the excess penetrant is dry before you start Step Three. That is not correct.

The objective in having the excess penetrant on the surface wet prior to starting removal is to make removal easier and assure that penetrant is not brought out of discontinuities. Before you start Step Three you can wet the dried excess penetrant by redipping, respraying, or rebrushing the article. You do not have to repeat the entire process at this point.

Return to page 4-1, reread the information and make the other selection.

From page 4-1

Correct. Start over with Step One if the excess dried after you have started Step Three. Now let's proceed with Step Three by adding it to the flow diagram.

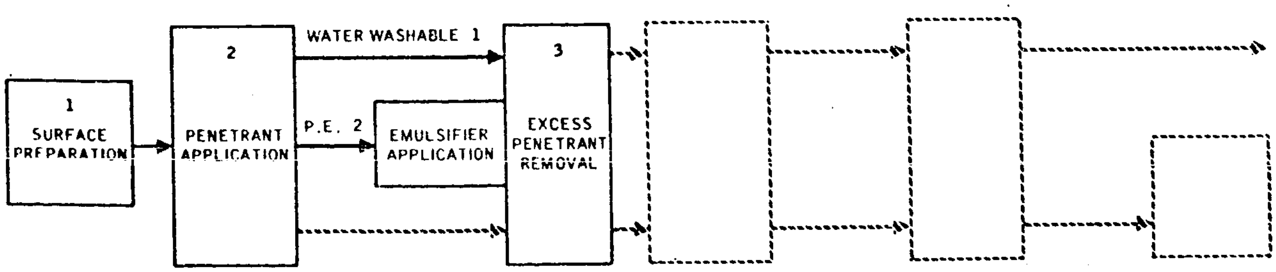


The method of removing the excess penetrant depends upon the type of penetrant used. We have previously determined that there are two categories of penetrants — fluorescent and visible-dye. For both categories there is a further breakdown. There are three types of penetrant: 1) Water washable 2) Post emulsification, and 3) Solvent removable. Two of these are soluble with water — their excess can be removed with water. These types of penetrant are:

Post-Emulsification (P. E.)

Water-Washable.

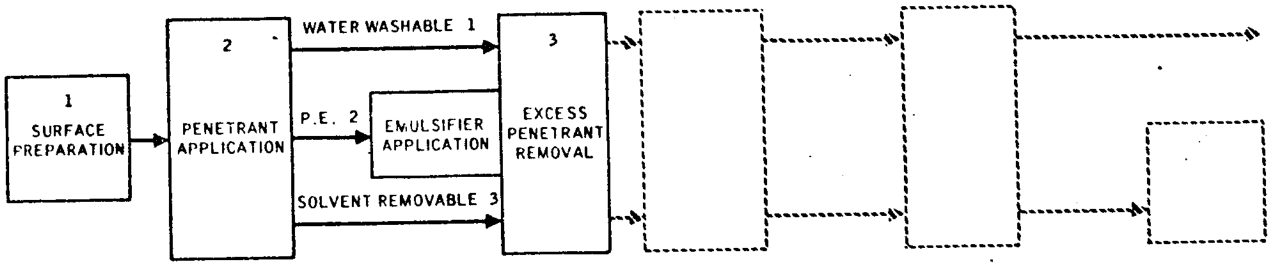
The excess of both of these is removed with water. We will discuss these later in this section but for right now here they are added to the flow diagram.



Turn to the next page.

From page 4-3

The third type of penetrant is not soluble in water so its excess cannot be removed with water. A special solvent is required to remove it from the surface. Let's call it . . . Solvent-Removable and add it to the flow diagram.



Let's review the penetrant types at this point.

Post Emulsification	}	. . . . Excess Removed With Water
Water-Washable		
Solvent-Removable		. . . . Excess Removed With Other Than Water

These types of penetrants are available with either fluorescent or visible dyes.

Taking the last one first, turn to the next page and see how the excess is removed when using solvent-removable penetrant.

From page 4-4

First, as much excess solvent-removable penetrant is removed with a clean, dry, lint-free cloth (or absorbent paper) as possible. Then the remainder is removed with another clean, lint-free cloth, dampened this time with a "penetrant remover." Penetrant remover is a solvent cleaner produced by the manufacturer of the penetrant specifically for the removal of his own type of penetrant. Only those penetrant removers recommended by the manufacturer of the penetrant may be used, and flushing the surface with penetrant remover is not permitted!

When using visible-dye penetrants, a check is made to insure all excess penetrant has been removed in the following manner: Take another clean cloth and wipe it over the surface. If it fails to show traces of the dye color (usually pink or red) the surface has been properly cleaned of excess penetrant.

When using fluorescent dyes, the excess penetrant is removed under a black light. The operator can easily tell when the excess penetrant has been removed.

Is this statement true or false?

Trichloroethylene or ethyl alcohol could be substituted as a penetrant remover in order to reduce production costs.

True ....Page 4-6

False ....Page 4-7

Your answer is not correct.

First, remember we are talking about only one of the three types of penetrants available, the solvent-removable type.

Only penetrant remover recommended by the penetrant manufacturer can be used. In most cases the penetrant manufacturer will also make a penetrant remover. Penetrant and penetrant remover will be purchased together. Only when recommended by the penetrant manufacturer could other penetrant removers be used. That won't happen often. Thus, even though we are always interested in savings, the savings themselves could not justify the substitution of trichloroethylene or ethyl alcohol.

The correct answer, you'll now agree, is false. With this point in mind, turn to page 4-7 where we'll continue this program.

From page 4-5

Good. You are correct.

Remember, when using solvent-removable penetrant:

1. Remove as much excess penetrant as possible with dry wipers.
2. Remove the remaining excess with remover-dampened wipers.
3. When using visible-dye penetrants, check for complete removal by noting that the last remover-dampened wiper is "pink-free" or when removing fluorescent dye, check with black light.

Excess penetrant must, of course, be thoroughly removed to avoid false indications that might result in the rejection of acceptable components. When removing solvent-removable penetrants, there is a definite taboo — something that you must not do.

EXCESS PENETRANT MAY NOT BE FLUSHED OFF
WITH THE PENETRANT REMOVER.

The object is to remove <u>excess</u> penetrant from the surface of the article without removing any penetrant from any discontinuities that might exist.

Now that we have seen the technique for removing excess solvent-removable penetrant, turn to the next page for a study of removing excess water-washable penetrants.

From page 4-7

Let's look at the first type of penetrant — water-washable penetrant. Water-washable penetrant has a built-in emulsifier. An emulsifier is a chemical that has been added to the penetrant that makes the penetrant soluable in water. A penetrant having an emulsifier in it will wash off with water. Herein lies the danger. Haphazard washing, called "over-wash," can remove the penetrant from discontinuities as well as from the surface!

A coarse, forceful water spray has been found to work best for removing water-washable penetrant excess. If the dye used is fluorescent, it is recommended that the wash be conducted under black light. You can see why. As a surface covered with fluorescent-dye penetrant will glow vividly before the wash, you can easily tell when the excess surface penetrant has been washed away. The surface will no longer fluoresce. Only the discontinuities would glow after a proper wash conducted under black light.

There is one other recommendation to keep in mind when using a water wash to remove excess penetrant. The temperature of the water used should not be above 110°F. Water at temperatures above 110°F are not recommended because it speeds vaporization of the penetrant. When this occurs to penetrant in the discontinuities, some of the penetrant's power to later produce a vivid image of the discontinuity may be lost. To guard against this possibility, watch the water wash temperature. Keep it below 110°F.

Excess water-washable penetrants are removed with a coarse,
forceful spray of water whose temperature must be over 110°F . . . . Page 4-9

Excess water-washable penetrants are removed with a coarse, forceful
spray of water whose temperature must be under 110°F . . . . Page 4-10

Slow down a bit. You have selected the answer that states that the temperature of the water wash must be above 110°F. This is incorrect.

If the temperature of the wash is over 110°F the heat of the water will help the penetrant to vaporize right out of any discontinuities that may exist. In a tight crack, for example, there is only a very small amount of penetrant available, we can't take any chances on losing any of it. Therefore the temperature of the water wash must be below 110°F.

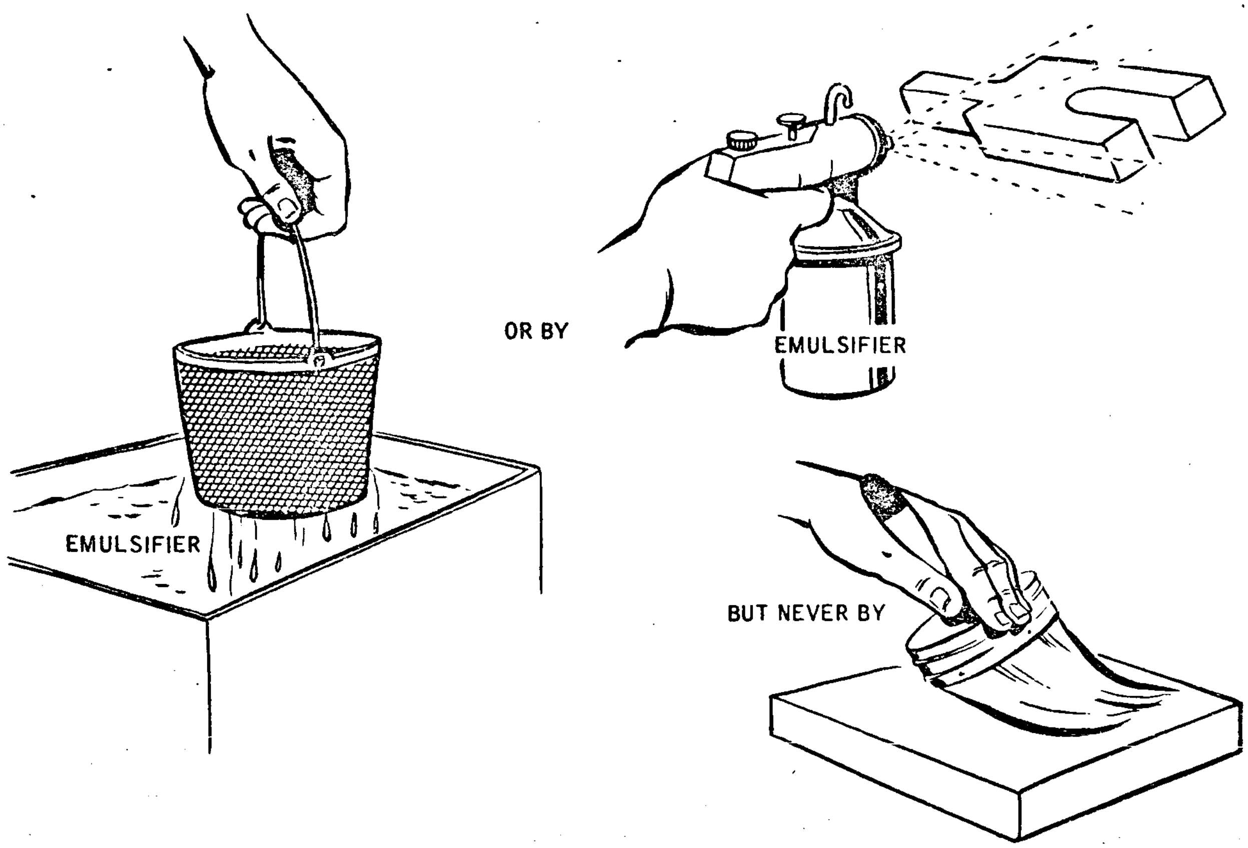
Now turn to page 4-10 and continue.

From page 4-8

Right. The temperature of the water wash must be below 110°F. We stated previously that both water-washable and post-emulsification penetrants can be removed with water. However, one of the two types will require an extra step before it becomes water soluble. This penetrant is the one called post-emulsification (P. E.) penetrant. The P. E. penetrant does not contain a "built in" emulsifier so emulsification is accomplished by adding a chemical emulsifier prior to washing that will break the penetrant down and make it water soluble.

The emulsifier can be applied in the same way as was the penetrant — with one exception. Never apply the emulsifier with a brush. Spraying is O. K. So is dipping, but brushing is out because the bristles of a brush are apt to "brush away" penetrant from shallow discontinuities!

Remember, with P.E. penetrants the emulsifier can be applied by ....



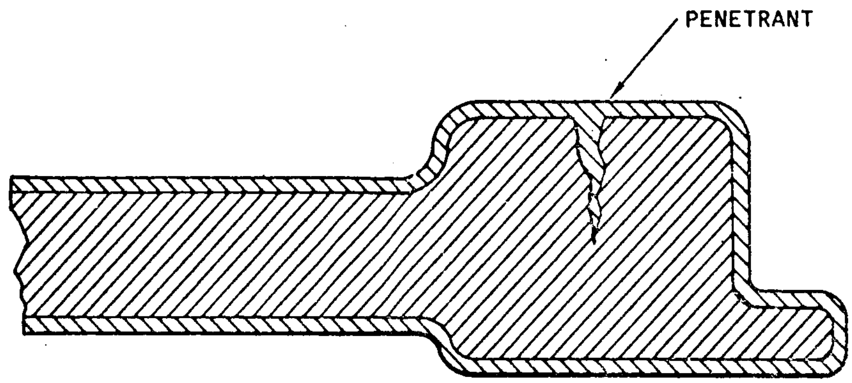
Note this one exception!

Turn to the next page.

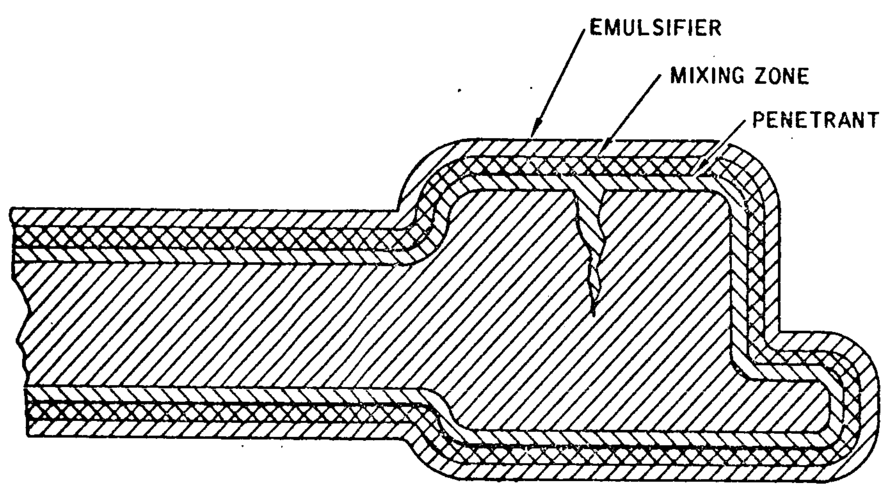
From page 4-10

In review, the additional operation required when post-emulsification penetrant is used is the addition of an emulsifier. Before its addition, this penetrant is not water-washable. After its addition, post-emulsification becomes water-washable.

Here is a surface coated with post-emulsification penetrant. Notice that sufficient penetration time has been allowed for penetrant to enter the discontinuity.



Here is the same article after the addition of the emulsifier.



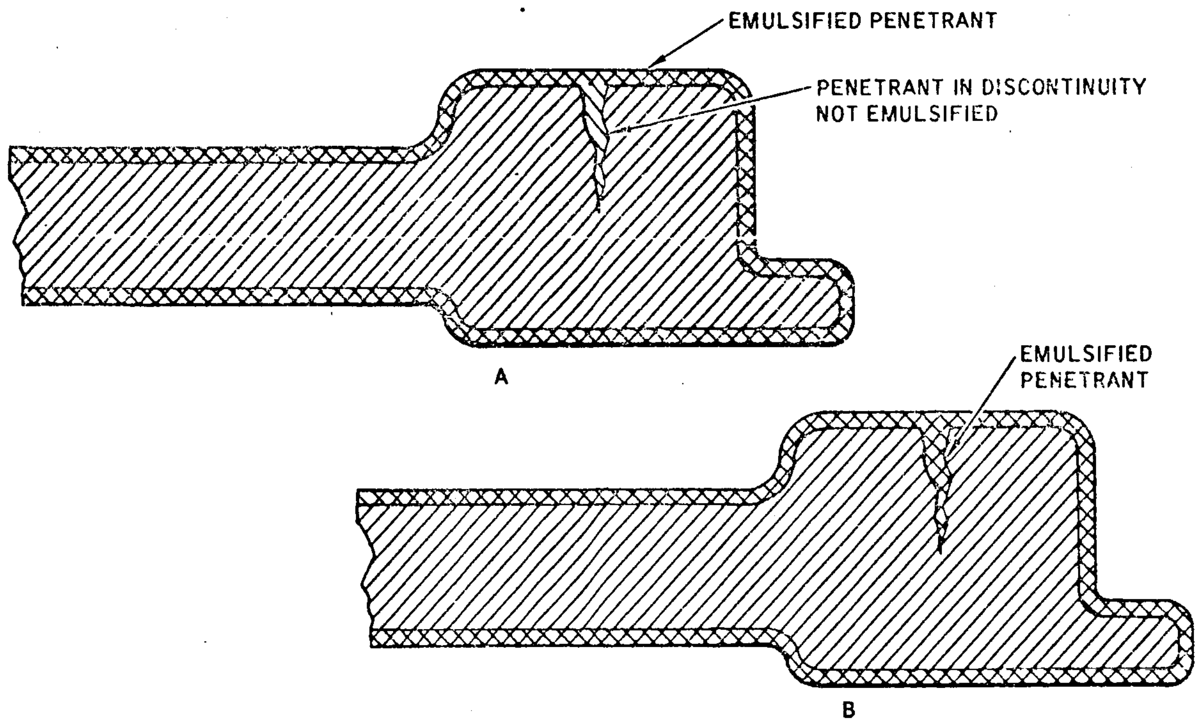
Notice that the emulsifier starts to work from the penetrant's surface, mixing with the penetrant as it works toward the article itself.

Turn to the next page.

From page 4-11

When post-emulsification is used, the most critical operation during the entire liquid penetrant process begins when the emulsifier is applied to the penetrant. The critical factor is time. How long a period should be allowed for this action?

The emulsifier is allowed to remain on the surface until it has mixed with the surface penetrant, but not long enough for it to mix with penetrant in the discontinuities. Let us show this with pictures. Here are two situations. On A, one time has been allowed for mixing. On B, a longer time has elapsed. Study them both with the following thought in mind: You do not want to remove penetrant from the discontinuity. Further, penetrant cannot be removed until the emulsifier added in this step has mixed with it.



Which of the above represents the proper emulsification time?

A . . . . Page 4-13

B . . . . Page 4-14

View "A" illustrates the proper emulsification time.

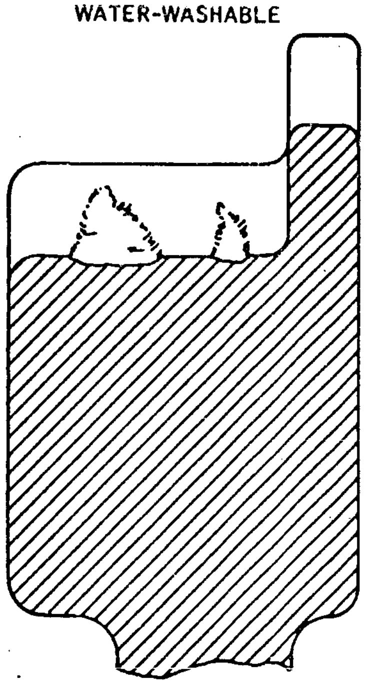
You can see that when we use post-emulsification penetrant, the emulsification time is critical. In fact, with this penetrant, the emulsification time is considered more critical than the penetrant dwell time!

What is the advantage in using post-emulsification penetrant?

Proper control of the emulsification period will prevent the removal or "over-wash" of penetrant from even the shallowest discontinuities! Let's see how. Below is a comparison of the two penetrants on two identical parts with shallow discontinuities. Let's call them View A and View B.

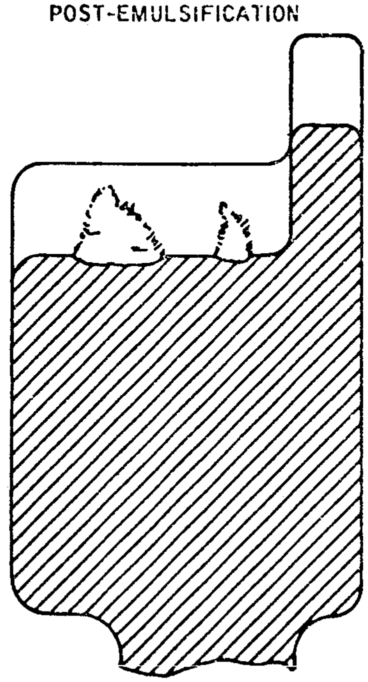
For View A, we will use water-washable penetrant. For View B, we'll use post-emulsification penetrant. (Note: The size and shape of the discontinuities in the following illustrations are exaggerated for teaching purposes. They are not intended to represent a typical shallow discontinuity.)

WATER-WASHABLE



VIEW A
CROSS-SECTION

POST-EMULSIFICATION

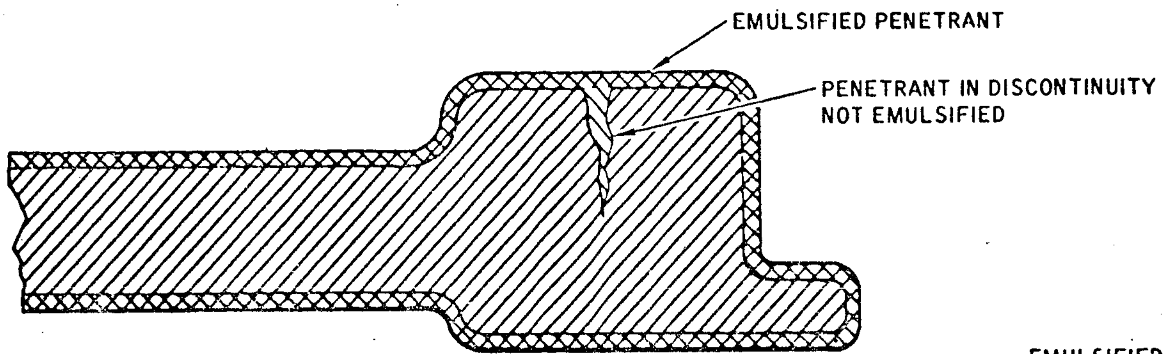


VIEW B
CROSS-SECTION

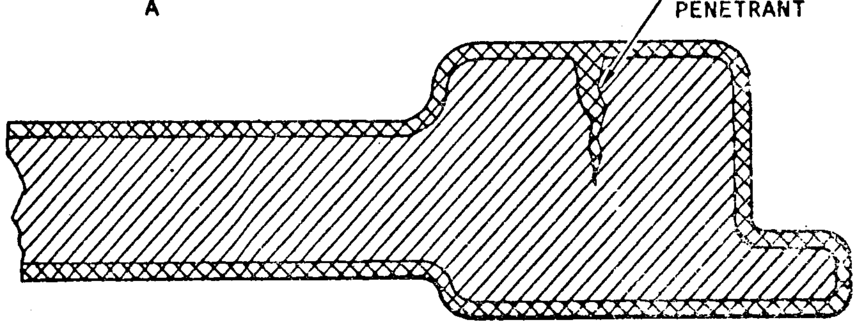
Turn to page 4-15.

From page 4-12

Let's take another look at the two pictures to solve this difficult problem.



A



B

Now the trick is to determine which surface has experienced the proper emulsification time. Study the pictures in terms of the following:

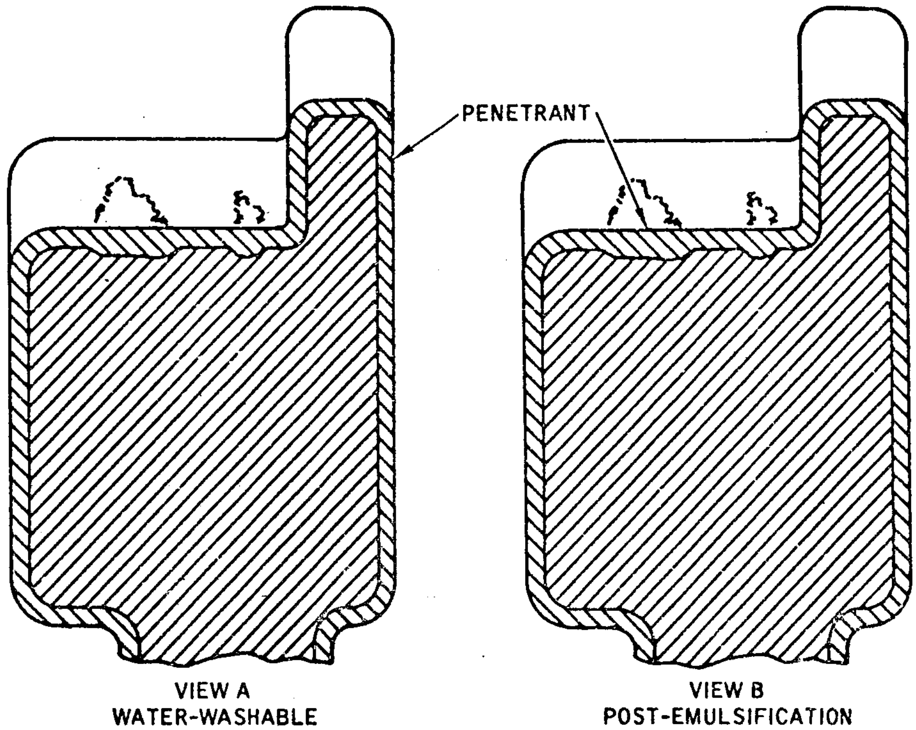
View A - This view shows that the emulsifier has had time to work its way from the surface of the penetrant down through the body of the penetrant until it is exactly at the surface of the article itself. The emulsifier has not worked its way into the penetrant inside the discontinuity. Remember these important considerations: You do not want to remove penetrant from the discontinuity: And, excess penetrant cannot be removed with water spray until it has mixed with the emulsifier. By applying a water rinse to A as it is shown above, you would be rinsing away only excess penetrant from the surface of the article and would not remove any penetrant from the discontinuity. This represents the ideal emulsification time.

View B - This view shows that the emulsifier has had time to work its way from the surface of the penetrant down into the discontinuity. So what happens when a water spray is applied to remove excess penetrant? Excess penetrant is removed alright, but so is some of the penetrant from the discontinuity. This condition shows too long an emulsification time and will not make for a very effective test in the later steps of your test procedure.

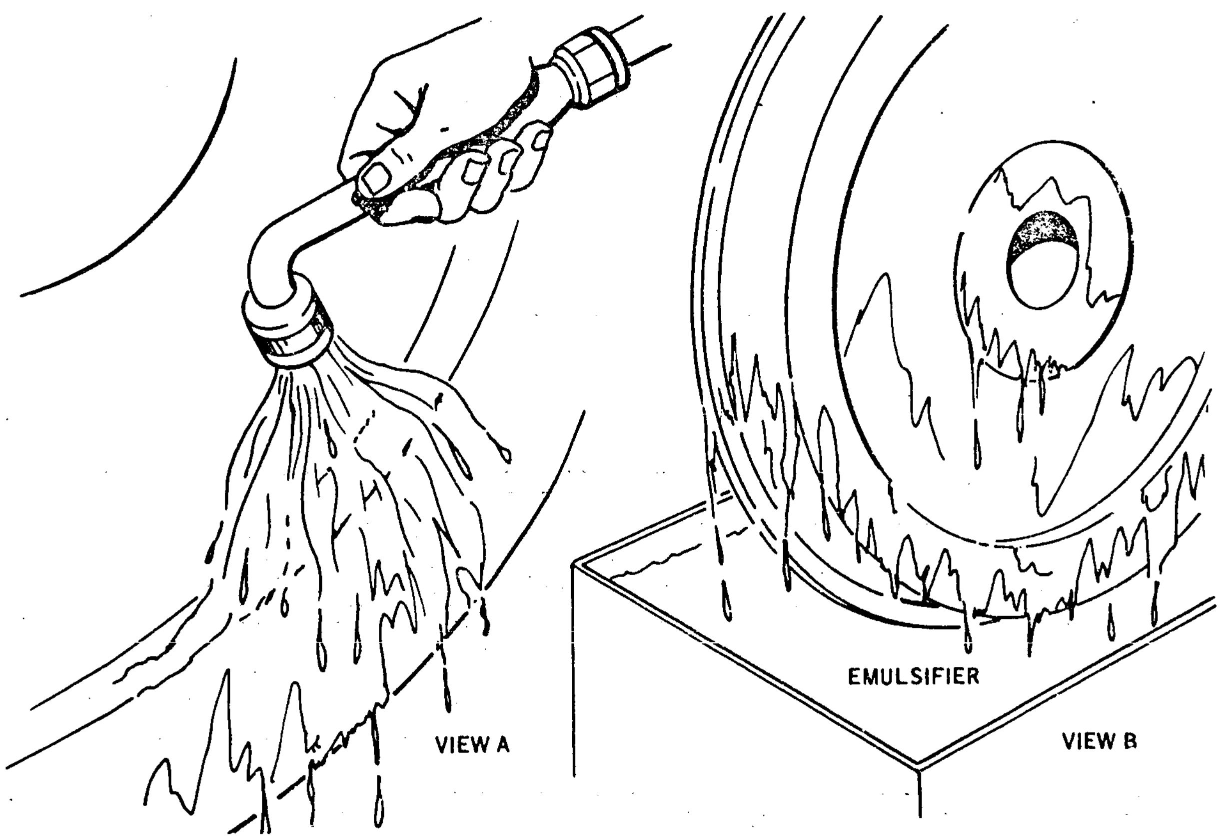
Turn to page 4-13.

From page 4-13

After the proper penetrant time they look like this.



Now, apply wash to View A and .... apply the emulsifier on View B.



Turn to the next page.

5380-10

From page 4-15

After careful control of the emulsification time, "B" is washed.

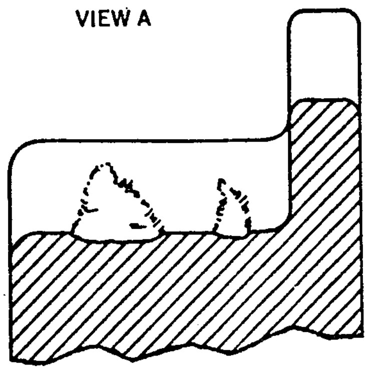
Notice that it is washed in the same manner as was "A." A coarse forceful water spray is used. And the same water temperature maximum is recommended — 110°F.

Remember also, the wash was a critical point with "A" because water-washable penetrant was used. The wash is not the critical point when P. E. penetrant is used. The emulsification timing is critical instead.

Turn to the next page.

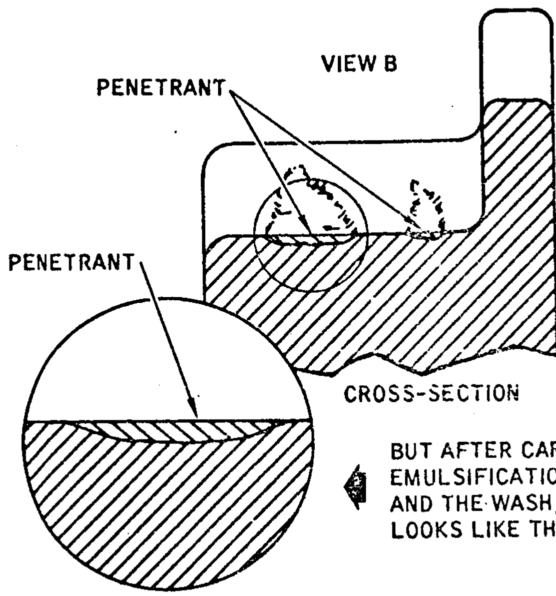
WATER-WASHABLE

VIEW A



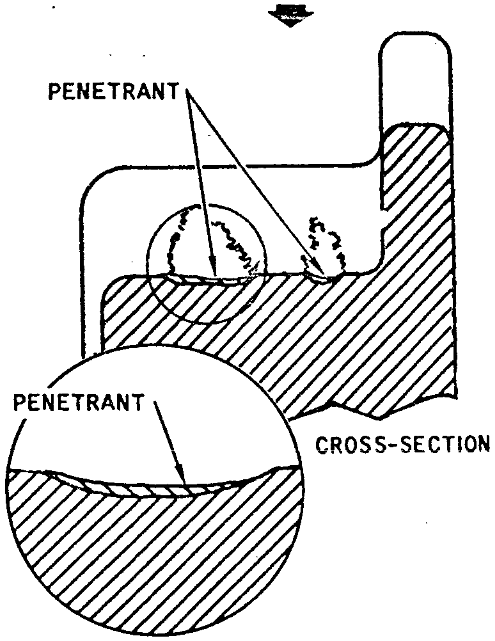
AFTER "OVER WASH" VIEW "A" WOULD LOOK JUST THE WAY IT DID BEFORE PENETRANT APPLICATION.

AS SHOWN ON THE LEFT NO PENETRANT REMAINS IN THE DISCONTINUITIES!



BUT AFTER CAREFUL EMULSIFICATION CONTROL AND THE WASH, VIEW "B" LOOKS LIKE THIS!

EVEN WHEN MOST CAREFULLY WASHED, SOME PENETRANT WILL BE LOST FROM VIEW "A'S" DISCONTINUITIES, AS SHOWN BELOW.



If you were required to use a fluorescent penetrant to locate suspected <u>shallow</u> discontinuities, which of the following would be your course of action?

I'd use a post-emulsification penetrant .... Page 4-18

I'd use a water-washable penetrant .... Page 4-19

Fine! Post-emulsification penetrant has advantages that would make it a good choice when a penetrant is used to locate shallow discontinuities.

Now you can see why the emulsification time is critical when we use post-emulsification penetrant. In fact, with this penetrant, the emulsification time is considered more critical than the penetrant dwell time.

Under normal circumstances the test operator will be supplied the emulsification times that should be used for the test that he is conducting. The correct time has been determined by experimentation with a similar article with known discontinuities. Several tests are conducted using different emulsification times. The time selected is the one that produces the best results.

There is one important difference between emulsification time and penetration time that you must remember. Whereas the penetration times were minimum and no maximum time was insisted upon, this is not the case with emulsification times. The emulsification time is a specific time and must be carefully controlled. If too short a time is used not all penetrant on the surface will be removed and the remaining penetrant will tend to cloud over discontinuity indications. If too long a time is used, penetrant within the discontinuities will also become water-washable and be washed away along with the excess penetrant.

Which of the following would be the best reason for selecting P.E. penetrant to test for shallow, open discontinuities?

The water wash is less critical . . . . Page 4-20

The penetrant dwell time is less critical . . . . Page 4-21

This is not the best choice.

When a water-washable penetrant is used it is very easy to wash the penetrant out of any shallow, wide open, discontinuities. Therefore, whenever you are looking for such discontinuities we would recommend post-emulsification penetrant over water-washable.

By carefully controlling the emulsification time, the emulsifier does not mix with the penetrant in discontinuities. Excess post-emulsification penetrant does not become water-washable until mixed with emulsifier. The emulsifier is applied over a surface covered with penetrant. It begins to mix with the penetrant, moving from the surface toward the center.

Now turn to page 4-18 and continue.

From page 4-18

Good for you!

Since the wash is less critical when P.E. penetrants are used, there is less chance of removing penetrant from shallow discontinuities. When water-washable penetrants are used there is always this possibility, even when the utmost care is observed to avoid "over wash."

Both of the penetrants (water-washable and post-emulsification) carried a dye in suspension. If the dye is "fluorescent dye," it is visible only with the aid of black light. If, prior to beginning the water rinsing stage, an article covered with fluorescent penetrant were held under black light, the entire surface would glow with the fluorescent dye's characteristic yellow-green brilliance. This suggests a washing technique that will ensure the surface has been cleaned of all excess penetrant. The technique is stated below. Can you spot it?

Consult a chart for the proper wash time . . . . Page 4-22
Use a solvent cleaner in place of water . . . . Page 4-23
Wash under black light . . . . Page 4-24

From page 4-18

Remember now, both of the penetrants require a specified minimum dwell time. Both are important considerations but the dwell time for P. E. penetrants is not any more critical than the dwell time for water washable penetrants.

Turn to page 4-20 and let us show you a better reason for using P. E. penetrant in this case.

You would consult a chart for proper wash time to ensure that all excess fluorescent penetrant has been removed from the surface of an article. This would be a logical method if there were such a chart. However, your choice in this instance was incorrect. Keeping in mind that you are looking for the fluorescent reflection of the penetrant, return to page 4-20 and select another alternative.

To ensure removal of all excess fluorescent penetrant from the surface of an article you would use solvent cleaner in place of water. This is not correct. Remember that you are using a water-washable penetrant that is designed to be most effective when rinsed with a water spray. Keeping in mind that you are looking for the fluorescent reflection of the penetrant, return to page 4-20 and select another alternative.

Use of black light during the washing of excess fluorescent penetrant from the surface of an article will indeed ensure the surface has been cleared of all the excess. Good for you! Your answer was correct.

Let's review Step Three! Turn to page 4-25.

From page 4-24

1. Step One is ____________ ____________________ .
2. Step Two is ____________________ ________________________ .
3. Step Three is E_____________________ P_______________________ R_______________ .

5. water

6. Excess solvent-removable penetrants are considered non-w__________ -w__________ and are removed with clean lint free rags and/or especially manufactured penetrant re________________ .

10. water
    coarse
    spray

11. A water wash temperature above ________°F is not recommended.

15. emulsification
    penetration (or dwell)

16. There are many permissible ways in which to apply the emulsifiers but there is also one way which is not permitted because doing so could remove penetrant from within discontinuities. You may never apply the emulsifier with a b______________ .

1. Surface Preparation
   Penetrant Application
   Excess Penetrant Removal

2. Penetrant that has not entered a discontinuity at the completion of the "dwell" time is considered ________ penetrant.

6. Non-Water-Washable
   remover(s)

7. Excess solvent removable penetrant must be removed with a p______________ r______________ recommended by the manufacturer of the penetrant that has been used.

11. 110°F

12. Before <u>any</u> P. E. penetrant can be removed with water, however, an "extra" step must be taken. In this extra step, e__________ will be added.

16. brush

17. And to conclude this review of Step Three, here is a helpful point to remember. When fluorescent, water-washable, or fluorescent, post-emulsification penetrant is used, washing under ____________ ____________ is recommended to ensure that all excess is removed!

2. excess

3. If, prior to beginning Step Three, you find the penetrant has become dry or set, you may return and repeat Step Two's ____________ ________________.

7. penetrant remover

8. There are two types of water-washable penetrants. They are identified by the manner in which the ____________ penetrant is removed.

12. emulsifiers

13. The emulsifiers mix with the penetrant, working their way through the penetrant from the surface inward. If too long an emulsification time is allowed, penetrant in the ______________ies as well as ____________ penetrant will become water-washable.

17. black light

18. Now, let's take a look at Step Four. Turn to the next chapter.

3. Penetrant Application

4. Once you have begun Step Three's excess penetrant removal and for any reason you must repeat a step, you must begin again with Step _____.

8. excess

9. One penetrant that can be removed with water is called ____________________. The second is called ________ ____________________ penetrant or "____________" penetrant for short.

13. discontinuities

excess

14. The time allowed for this mixing is called the ____________ time.

4. One

5. The methods chosen for excess penetrant removal will depend upon the type of penetrant used. Excess P. E. penetrants will be removed with w_______________ .

Return to page 4-25, frame 6.

9. Water-washable
Post-emulsification
"P. E."

10. The excess of both of these penetrants is removed with _______________ and a __________ forceful water __________ is recommended for the job.

Return to page 4-25, frame 11.

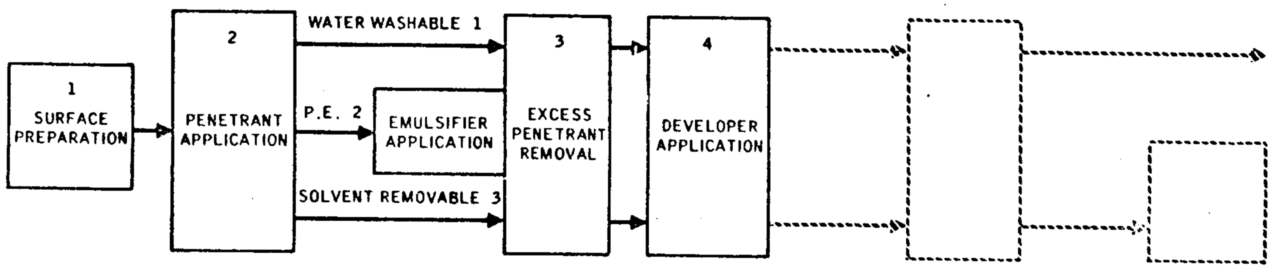
14. emulsification

15. When P. E. penetrants are used, the _______________ time is more critical than the p____________________ time.

Return to page 4-25, frame 16.

We are now ready for Step Four.

Some discontinuities may be visible at the conclusion of Step Three. (This would depend upon their size, location, etc.) Step Four, however, will ensure that all discontinuities are visible to the naked eye. In this step, a developer is applied to make this possible. Our flow diagram will look like this with Step Four added.



A developer was used in the Oil and Whiting method also. It was one of the following:

A white powder . . . . Page 5-2
Kerosene . . . . Page 5-3
Trichloroethylene . . . . Page 5-4

Correct.

A white powder served as the developer. The developer was used in the Oil and Whiting days for the same purpose it is used today — to blot the dye-carrying penetrant back to the surface. It is not strange, then, to find that today we also use a whitish powder to do the job. It is a highly absorbent powder and is applied to the item being inspected after excess penetrant is removed. The developer absorbs the dye-penetrant from the discontinuities with a blotting action, spreading the dye to form visible indications. The blotting action of the developer is capillary action at work again! The dye-penetrant is actually drawn out of the discontinuity through the strong capillary action provided by the developer. The developer acts as a blotter. It is used for one reason — to get the dye back to the surface so that it will form an image of the discontinuity. The image of the discontinuity is formed in the developer itself as the dye carrying penetrant spreads out around the edges of the discontinuity it has left. In this manner, even slight traces of penetrant are drawn from discontinuities and, as they diffuse in the developer, their film thickness is increased and the penetrant is "fixed" in the developer. The fixing of this penetrant keeps an indication in place by preventing its bleeding and dissipation.

When we see a discontinuity indication, we are actually seeing dye which is diffused in the developer. Therefore, we can expect to see an indication that is one of the following:

Smaller than the discontinuity . . . . Page 5-5
Larger than the discontinuity . . . . Page 5-6
The same size as the discontinuity . . . . Page 5-7

From page 5-1

Oh Oh! We didn't stress the role of kerosene in the old Oil and Whiting procedure strongly enough.

We just mentioned, briefly, that kerosene served as the penetrant. And it is quite possible that the equally brief mention of a "white powder" serving as the developer . . . . was inadequate too!

Only one way to correct the oversight — mention them both again.

Here goes. In the Oil and Whiting method . . . kerosene served as the penetrant AND . . . a white powder served as the developer! Correct?

Turn now to page 5-2 . . . . and we'll take a look at developer use today.

"Trichloroethylene" is an impressive word. But it was not mentioned in connection with the old Oil and Whiting liquid penetrant inspection. Trichloroethylene did not serve as the developer. But it serves well today in another function. It is the solvent which is used in the vapor-degreaser cleaning we mentioned.

But we still face the question. "What was used as the developer in the Oil and Whiting method?"

Here's a clue. The penetrant kerosene is in reality "kerosene oil"; hence the word "oil" in the term Oil and Whiting. The word "whiting" is equally descriptive of the material used as the developer!

Turn now, with this clue in mind, and look over the choices on page 5-1 again. Select another one.

From page 5-2

Remember our goal in liquid penetrant testing!

To make the discontinuities easy to see.

Now, for a minute or two reconsider your answer to the question about the size of the discontinuity images which you'll see. You were given three choices (smaller, larger, the same size) concerning the size of the discontinuity which the images represent. You chose "smaller."

We feel certain that, with our liquid penetrant goal in mind, you'll make another choice now.

Here's the question again, followed by the remaining two choices. Choose again! When we see a discontinuity indication, we are actually seeing dye which has spread in the developer. Therefore, we can expect to see a discontinuity image that is one of the following:

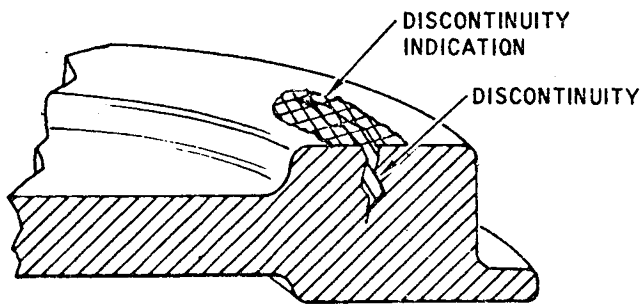
Larger than the discontinuity . . . . Page 5-6

The same size as the discontinuity . . . . Page 5-7

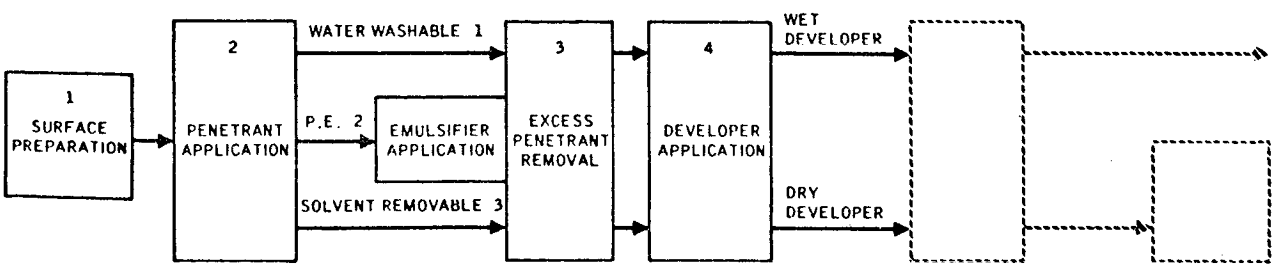
From page 5-2 (or 5-5)

Fine. We want to make it easy to see the discontinuities. So we've used a process that will make them easier to see. The discontinuity images will be slightly larger than "life size."

A typical indication would look like this:



There are two types of developers in use today to get this job done. They are called "wet" and "dry" developers. Both use a white powder as their essential blotting ingredient. The primary difference is the manner in which each is applied. Here's our flow diagram with wet and dry developer added.

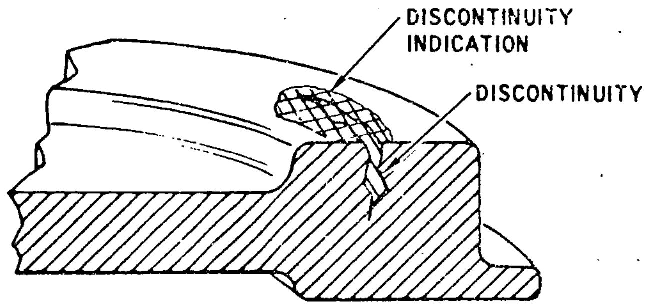


Turn to page 5-8.

From page 5-2 (or 5-5)

Your choice was not correct.

Here is the statement again: "Since, when looking for a discontinuity, we see the dye which is diffused in the developer, we can expect to see a discontinuity image that is ..." Your choice was: "The same size as the discontinuity." Perhaps a picture will best show you why this is not the case.



The developer has drawn the dye-penetrant up out of the discontinuity. The penetrant then spreads through the developer as shown in the shaded area in the picture. The amount of "spread" is determined by the amount of penetrant present in the discontinuity.

Keep this picture in mind, return to page 5-2, and select the correct answer!

From page 5-6

Let's look at each developer separately — first, the wet developer.

There are two types of wet developers. In one, the white powder is held in suspension in a solvent (non-aqueous) base. This type of developer is usually supplied in pressurized spray cans. After application, a short time is allowed for the solvent to evaporate and leave the article thinly coated with a layer of powder. This non-aqueous developer is generally used with solvent removable penetrants.

In the second type of wet developer, the white powder is held in suspension in water. Water based developers are generally used with water-washable or P.E. penetrants and are applied by dipping or spraying. When applying a water based developer by dipping, be certain that all water has drained from the pockets and recesses of the article after the wash. Although the article need not be thoroughly dry, if large amounts of water are carried over and added to the developer during repeated operations, the developer's consistency will be altered and its actions less predictable. The developer is then considered contaminated.

After application to the article, a short time is allowed for the water to evaporate. The evaporation is often accelerated with the use of a recirculating hot-air dryer. When such a dryer is used, however, the maximum drying temperature may range up to, but not in excess of 225° F. Why 225° F? To prevent evaporation of penetrant from within the discontinuities.

Dryer temperature is restricted to less than 225° F so that....

. . . penetrant will not be lost .... Page 5-9

. . . critical articles will suffer no damage .... Page 5-10

. . . wet developer will not evaporate .... Page 5-11

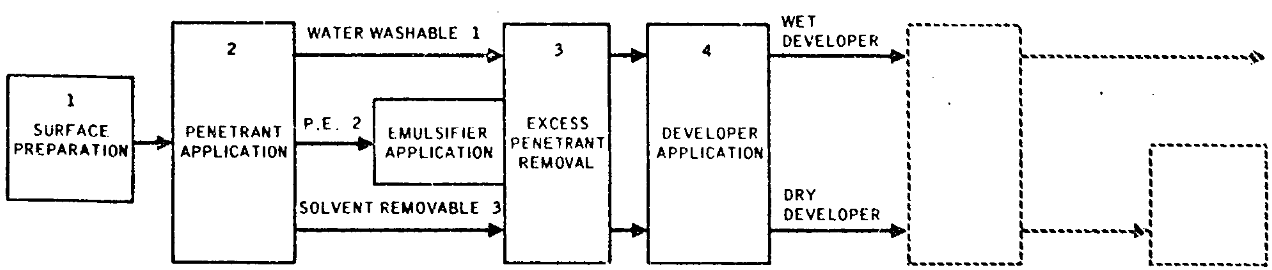
From page 5-8

Dryer temperature is restricted to less than 225° F to prevent evaporation of penetrant. Good for you .... correct again!

Here is a note of warning, however. Although we have quoted a temperature of 225° F as a maximum to prevent evaporation of penetrant, there are many conditions or situations in which 225° F is too high for other reasons. For example, certain penetrants can be damaged at temperatures above 180° F, and there are protective coatings that could be damaged at temperatures as low as 130° F. For these reasons, a maximum temperature should be established for each particular job.

Care must always be observed in keeping wet developers in a covered container when not is use. If not, the consistency, or balance, between the base and the powder will be altered by evaporation and the developer will be considered contaminated.

Take another look at our flow diagram as we turn our attention to dry developers.



Dry developers are used for the same purpose as wet developers — to blot penetrant back to the surface. The difference between wet and dry developers is ....

.... The dry developer is not carried in a liquid .... Page 5-12

.... The dry developer is applied in powder form .... Page 5-13

.... The surface must be dry before dry developer can be applied ..... Page 5-14

.... All of the above .... Page 5-15

From page 5-8

Your concern that critical articles may suffer damage is commendable, but limiting dryer temperature to "less than 225° F" will not guarantee safety of the test article without being more specific. What about delicate plastics, etc.? The upper limit of 225° F might well be too high for them. (Naturally, when materials are unusually sensitive to temperatures, special temperature restrictions will apply.)

The object in always restricting dryers to temperatures below 225° F is to protect the one material that we know will always be present, and which is always subject to adverse effects when the temperature gets above the 225° F mark. What is this material? It is the penetrant. What can happen to it? The answer to that one is included in the proper choice on page 5-8.

Now turn to page 5-8, re-read the page, and select the answer!

We'd better run through our introduction to dryer use again. We didn't make our point on the first go-around.

You have stated that dryer temperature is restricted to a 225° F maximum so that.... "wet developer will not evaporate." That answer is not correct. We want the developer to evaporate! The dryer is used after water-based wet developer application to help evaporate the moisture and leave the white powder thinly spread over the article.

Dryer temperature is restricted to temperatures below 225° F for another reason. Return to page 5-8 and give it another try! Re-read the page. The correct answer's right there.

Right you are, the dry developer is not carried in a liquid (as is the wet). But .... did you take time to read the other selections?

Here they are again:

... the dry developer is applied in powder form.

... the surface must be dry before dry developer can be applied.

... all of the above.

Take a second to look at the first two. They're also correct!

Dry developer will be given you in powder form. Remember the white powder from the Oil and Whiting method? Your dry developer will be supplied in a similar form, as a dry powder.

And if this is true, you can see that you'd need a dry surface if you wanted an even layer of powder. A thin, even layer of developer was the end sought with wet developer remember. The same end is sought with dry developer.

Let's look at the dry surface requirement a little closer. Go ahead and turn to page 5-15. We're sure your answer will now be, "all of the above." Right?

From page 5-9

Right. Wet developer is applied in liquid form, as one might just guess from its name. And no more surprising, dry developer is applied in powder form.

This choice was, perhaps, the "most" true of these presented, but we certainly didn't want to force such a mealymouthed "mostish" decision upon you. (That's the reason for the "... all of the above" choice. All of the statements were legitimate differences between wet and dry developers. Here they are again, see if you don't agree.

... the dry developer is not carried in a liquid

... the dry developer is applied in powder form

... the surface must be dry before dry developer can be applied

and the final choice, we know will now be yours, complete with directions to your next page.

... all of the above . . . . Page 5-15

This statement ... "the surface must be dry before dry developer can be applied" is most important — for dry developer. Not so for wet developer application. Therefore, this point marks a true difference between wet and dry developers. But why is this dry surface necessary? Because:

... the dry developer is not carried in a liquid, and

... the dry developer is applied in powder form.

These statements also mark a difference between wet and dry developers. Do the statements seem, perhaps, familiar? They were two of your other three choices on page 5-9. Since your choice of statements correctly spotted a true difference between wet and dry developers, and these other two statements are also true differences between wet and dry developers, the third choice — "... all of the above" — would be safe. It included all of them as representing true differences between wet and dry developers!

The third choice is below — follow the page direction.

... all of the above .... Page 5-15

Fine! "All of the above" was the correct choice.

Dry developer is a fine powder and is not carried in liquid. It is applied directly to the article as a powder. This can be done with a slight air pressure, such as from a rubber air-bulb or spray gun. Since the powder is very fine grained, articles may also be dipped into a container of dry developer. The excess powder is then shaken from the surface by tapping the item gently. You can readily see the necessity for a dry surface prior to application of a dry developer! A wet surface would result in an uneven layer of powder, or worse .... too thick a powder buildup as the powder forms a "mat" in the wet areas. When this occurs, discontinuity images are obscured by this thick mat-like buildup. Danger from a wet surface can be eliminated, however, by using the dryers in a slightly different sequence than when used with a water-based wet developer. The new sequence is listed below. Spot it?

Use the dryer before penetrant application .... Page 5-16

Use the dryer before developer application .... Page 5-17

Use the dryer after developer application .... Page 5-18

From page 5-15

Step One was surface preparation. Step Two was penetrant application. You are quite correct that the dryer oven is sometimes used as a part of Step One. When? When water, which is considered a "contaminant," must be removed from a surface. However, the question asked was, "when are dryers used during developer application?"

You've learned that these dryers are used after water-based wet developer has been applied. They are used to speed the evaporation of the liquid part of that wet developer. A thin deposit of developer remains covering the article.

Are these dryers used in a different sequence when dry developer is used? You bet they are! In order to get a thin, even deposit of dry developer over the article, the article must be thoroughly dry prior to developer application. Dryers are used to do this job.

With this information you should have no difficulty in spotting the dryer sequence necessary when dry developers are used in Step Four.

Return to page 5-15 and see how you do.

From page 5-15

Answer: "Use the dryer before developer application." Good for you. You are correct.

The drying ovens used to speed evaporation of the liquids used in water-based wet developers, may also be used to dry the article prior to dry developer application ... and thus ensure the necessary dry surface.

Regardless of which developer is used, wet or dry, the dryer temperature must be limited to the maximum established for the test. In no case should this maximum exceed 225°F to prevent evaporation of the penetrant.

Turn to page 5-19.

Evidently we have not clearly distinguished between water-based wet and dry developers. When we do so, you'll have no further difficulty fitting the dryers into the picture. Here, let's try again!

In wet developer the powder is held in suspension in either a water or solvent. When this wet developer is used, the article is usually dipped into the developer and a short time allowed for the water or solvent to evaporate and leave the article thinly coated with a layer of powder. When water-based developers are used, the evaporative process is often hurried by the use of a recirculating, hot-air dryer after the developer has been applied.

Dry developer is applied dry .... in powder form. It too can be applied by dipping, but to avoid layers of developer which are too thick or uneven, the article must be dry prior to developer application. Dryers are used prior to developer application to accomplish this objective.

Now then, if the question were asked, "How can danger from a wet surface be eliminated when dry developer is used?" You could answer ...

... Use the dryer before penetrant application .... Page 5-16

... Use the dryer before developer application .... Page 5-17

From page 5-17

Now, see if you can specify the proper sequence for dryer use with a water-based wet developer. Study the procedure below and select the correct sequence for dryer use.

Step One. Surface preparation

Step Two. Apply the penetrant.

Step Three. Remove the excess penetrant.

USE THE DRYER .... Page 5-20

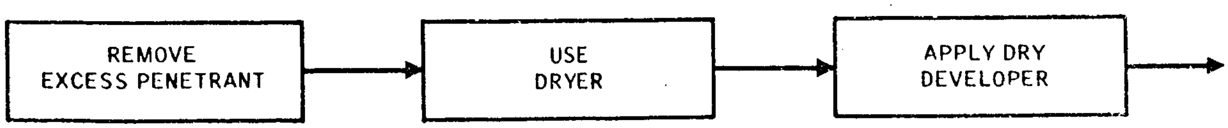
Step Four. Apply the developer.

USE THE DRYER .... Page 5-21

From page 5-19

Evidently we have not clearly distinguished between wet and dry developers. When we do so, you'll have no further difficulty fitting the dryers into the picture. Here, let us try again!

In wet developer, the powder is held in suspension either by a water or solvent. When this wet developer is used the test article is usually dipped into or sprayed with the developer and a short time allowed for the water or solvent to evaporate and leave the article thinly coated with a layer of powder. The evaporative process is often hurried by the use of a recirculating hot air dryer — <u>after water-based wet developer has been applied</u>.



Dry developer is applied dry....in powder form. It too can be applied by dipping, but to avoid layers of developer which are too thick or uneven, the article must be dry prior to developer application. Dryers are used <u>prior to dry developer application</u> to accomplish this objective.

Return to page 5-19, study the sequence presented and make the correct selection.

From page 5-19

OK! Fine. But how about dryer use with dry developer? Do you have that procedure down pat also? Choose the correct sequence.

1. Clean the surface.
2. Apply the penetrant.
3. Remove the excess penetrant.

USE THE DRYER . . . . Page 5-22

4. Apply the developer.

USE THE DRYER . . . . Page 5-23

From page 5-21

Excellent. You've recognized the need for using the dryer at a different point in the inspection process depending upon whether wet (water based) or dry developer is used. This brings up another point. What governs the choice of either wet or dry developer in a given situation? Here are a few uses for each:

USES FOR WET DEVELOPER

1. On very smooth surfaces where dry developers will not adhere.
2. When a large number of small articles are to be inspected a wet developer is easier to apply.
3. When wide, shallow discontinuities are sought, a wet developer tends to leave a more even coat of developer.

USES FOR DRY DEVELOPER

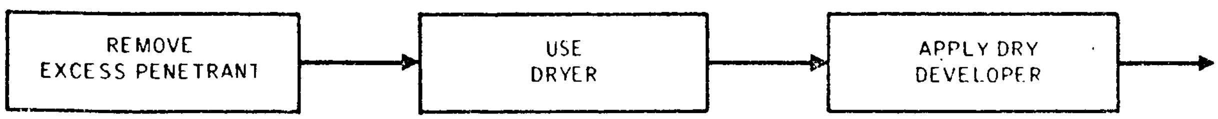
1. On rough surfaces dry developer gives far better results than wet developers.
2. On sharp fillets, holes, and threaded articles where wet developers tend to leave too much developer.
3. On very large articles where it may not be easy to apply a wet developer.

These rules are guides only. There are many exceptions. For example, on weldments of large articles specifications require a wet developer.

Turn to page 5-24.

Evidently we have not clearly distinguished between wet and dry developers. When we do so, you'll have no further difficulty fitting the dryers into the picture. Here, let us try again!

In wet developer the powder is held in suspension in either a water or solvent. When this wet developer is used, the article is usually dipped into or sprayed with the developer. A short time is then allowed for the water or solvent to evaporate and leave the article thinly coated with a layer of powder. When water-based wet developers are use the evaporative process is often hurried by the use of a recirculating, hot-air dryer after the developer has been applied.



Dry developer is applied dry .... in powder form. It too can be applied by dipping, but to avoid layers of developer which are too thick or uneven, the article must be dry prior to developer application. Dryers are used <u>prior to dry developer application</u> to accomplish this objective.

Return to page 5-21, study the sequence presented there, and make the correct selection.

From page 5-22

You might ask if there is a development time, similar to the penetration time. There is, and it should present no problem. A rule of thumb will give you the answer.

The development time is defined as the time from developer application to the time the article is inspected. Our rule of thumb tells to: use a time that is approximately one-half the penetration (dwell) time used.

If the penetration time was ten minutes, developer time would be approximately five minutes! That's all there is to it. This developer time, however, includes the time in the dryer oven. The time in the dryer is, as you may have guessed, not as critical as the temperature of the dryer. Whether it is used before developer application, as with dry developers, or after application, as when using water-based wet developers, the temperature must not exceed the maximum established for the test.

Development is a minimum time. It must be long enough to assure that the developer has had time to draw the penetrant from the discontinuity. If the article is inspected too soon, the indications may not have reached their maximum intensity and, therefore, be overlooked.

Turn to the next page for a review of Step Four.

From page 5-24

1. Step One is ________ ____________ .

   Step Two is __________ __________.

   Step Three is ______________ ____________ ___________.

   Step Four is _____________ _____________.

4. wet

5. When the developer is applied in its natural powder state, the developer is considered a ____________ developer.

8. discontinuities

9. The dyes in the penetrant drawn from the discontinuities diffuse in the ________________ and form an image of the discontinuity that is (larger) (smaller) _____________ than the actual discontinuity size.

12. development
    penetration
    (or dwell)

13. The development time is the ____________ (maximum, minimum) time allowed between application of the developer and the inspection of the article.

1. Surface Preparation
   Penetrant Application
   Excess Penetrant Removal
   Developer Application

2. If your testing is interrupted during Step Four or for any reason you feel it necessary to repeat one of the earlier steps, you must now return to Step ________.

5. dry

6. There are only two types of developers. There is the ________ developer and the ____________ developer.

9. developer
   larger

10. When drying ovens are used to speed Step Four they will be used (before) (after) ____________ application of the water-based wet developer.

13. minimum

The review of Step Four is now completed. You are now ready for Steps 5 and 6. Please turn to Chapter 6.

2. One

3. You've learned that a white __________ served as the developer in the old "Oil and Whiting" test method and that a ______________ is still used as the developer today.

6. dry, wet
(or wet, dry)

7. Both of the developers are used to blot penetrant from discontinuities back to the surface. For this blotting ability the natural force called ________________ ___________ is again required.

10. after

11. The dryers are used (before) (after) __________ dry developer application, but regardless of what type of developer is used, the dryer temperatures should never exceed __________ °F, and in many cases should be somewhat lower.

3. powder

powder

4. When the powder is suspended in a liquid, the developer is said to be a ______________ developer.

Return to page 5-25, frame 5.

7. capillary action

8. The developer will draw penetrant from the _______________ because the developer provides a stronger capillary attraction than that which has held it.

Return to page 5-25, frame 9.

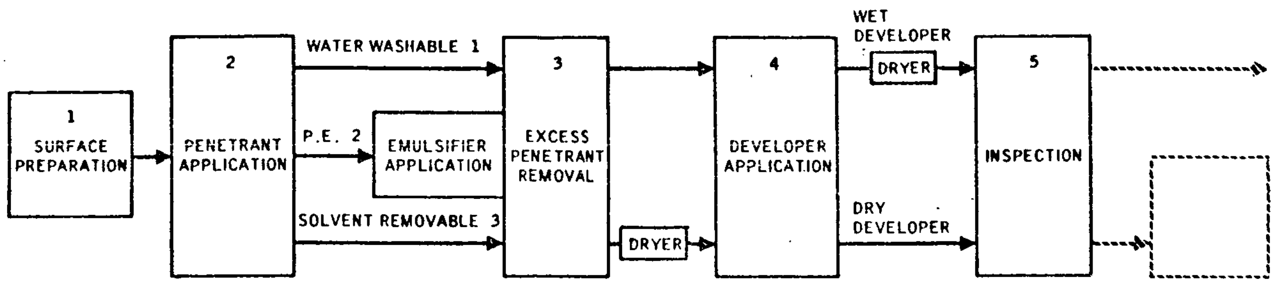
11. before

225°F

12. The period from developer application to the inspection of the actual discontinuities themselves is called the _________ment time. It should be approximately one-half the ______________ time.

Return to page 5-25, frame 13.

Step Five is INSPECTION. We are now going to take a close look at the specimen under test.



Proper lighting should be the first consideration in the inspection of an article. If a fluorescent-dye penetrant was used, a room or booth with black light will be required for the inspection. If a visible-dye penetrant was used, the inspection must be accomplished under adequate normal lighting. The inspection may reveal indications which are either true indications or non-relevant indications.

True Indications. These are indications that are caused by the penetrant bleeding out from actual discontinuities in the article. These indications are the ones we set out to find when we started the inspection.

Non-relevant Indications. As the name implies, these are indications that do not stem from actual discontinuities and are, therefore, not relevant to the determination of acceptability of the article. However, they do present problems for the tester. It must be determined that they are not true indications or do not conceal true indications. There are two common causes of non-relevant indications:

Turn to the next page.

From page 6-1

1. Failure to accomplish the liquid penetrant process correctly. (This type of non-relevant indication is sometimes called a "false" indication.) Indications from an incorrect process result from improper techniques such as failure to clean the article adequately in Step One or failure to remove excess penetrant in Step Three. Since a non-relevant indication of this type may hide true indications, the only acceptable corrective action is to start the process over with Step One.

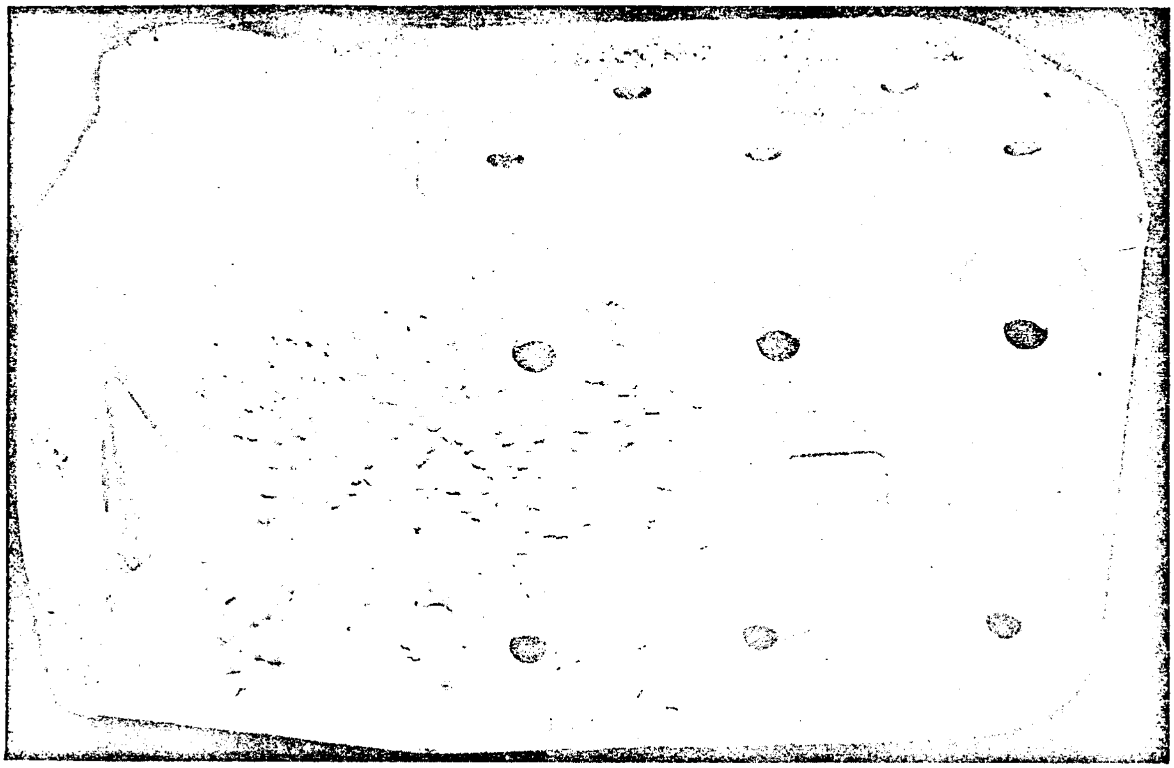
2. The second type of non-relevant indication results from rough or irregular surfaces of the article. Penetrant may be trapped in any irregularity of an article and give an indication when challenged by the developer. One example of this type of indication may be noted when testing a rough, unfinished surface. Another example may be encountered when testing press-fitted articles. A fit line will be present where the articles are joined and will appear as a straight line (as opposed to being crooked). It will appear as if it belongs there — and it does. The danger of this type of non-relevant indication is the same as in item (1) above. True indications may be concealed.

Learning to identify indications is one phase of the test which takes much practice. There are many types of discontinuities which you will be working with and we cannot teach them all to you here. No course in liquid penetrant testing should be considered complete until the student has had the opportunity to see the discontinuities as they appear on actual hardware items. The next few pages contain photographs which will show you just a few of the discontinuities you will be faced with in your further training and job performance.

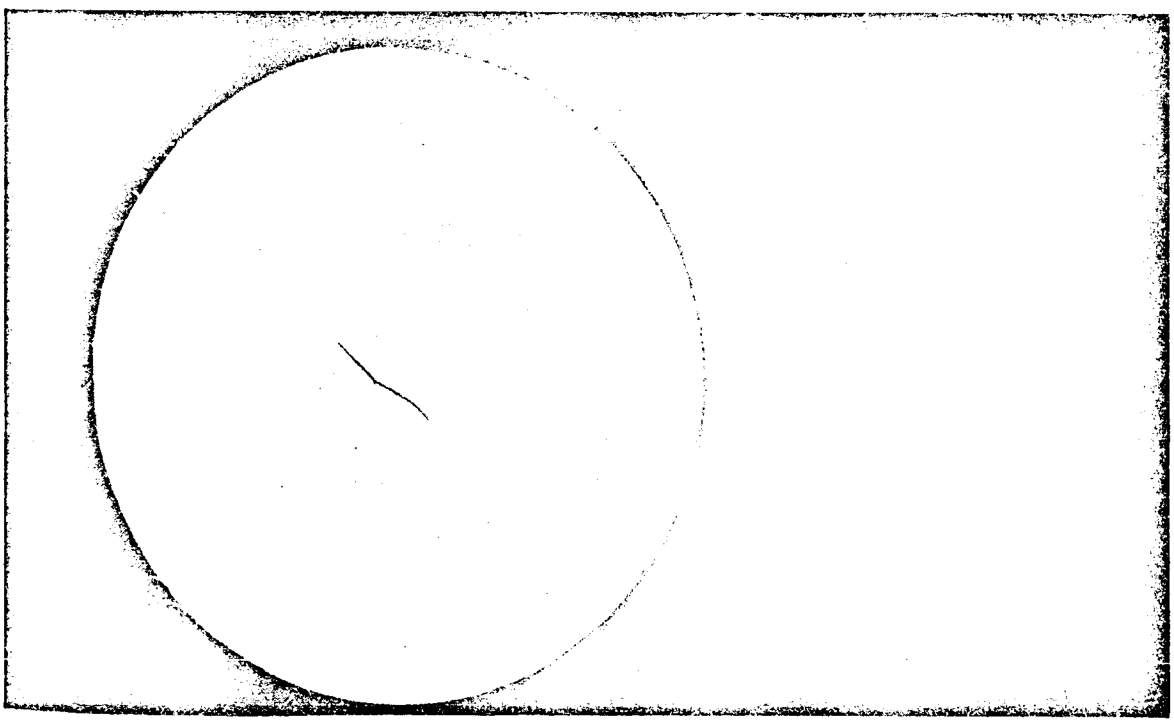
In examining these photographs you must realize that the actual discontinuities were not visible in the bare metal. They have become visible only as the result of the liquid penetrant process. The dye spreading through the developer has given us a larger-than-life sized indication of the discontinuity.

Turn to the next page.

From page 6-2



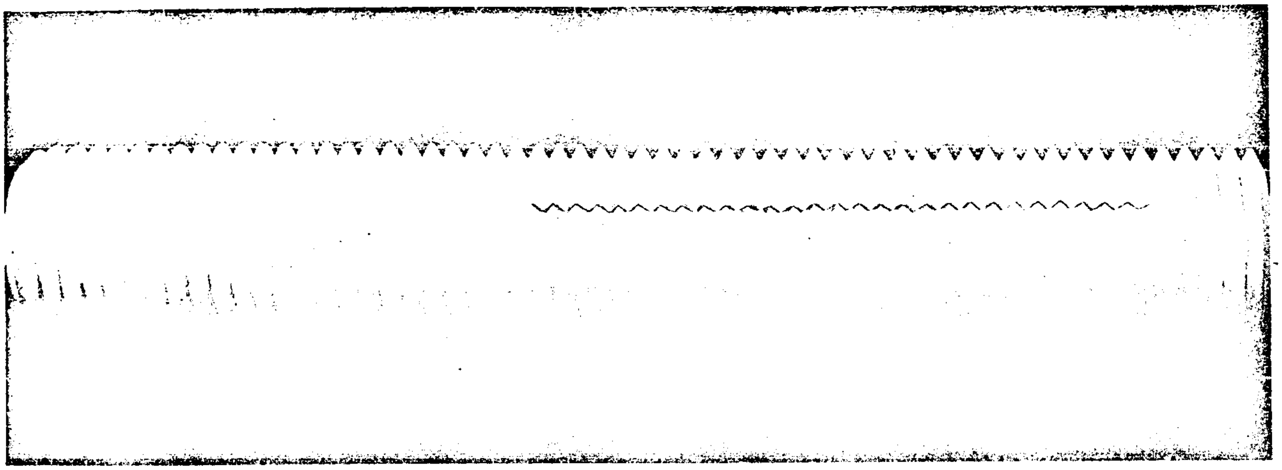
Surface Bursts in Steel Forging



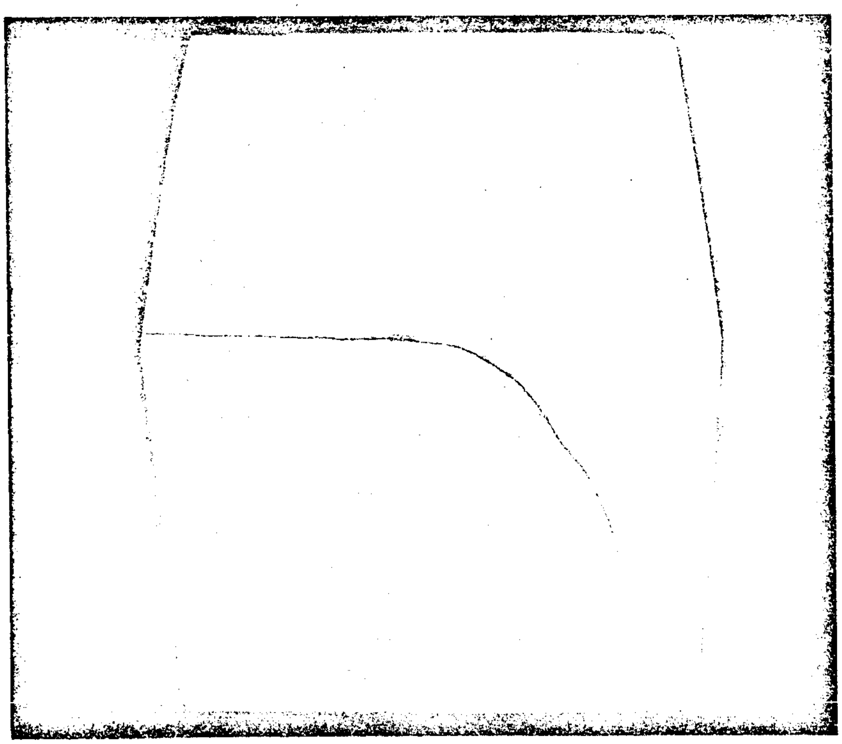
Internal Forging Burst

Turn to the next page.

From page 6-3



Seam

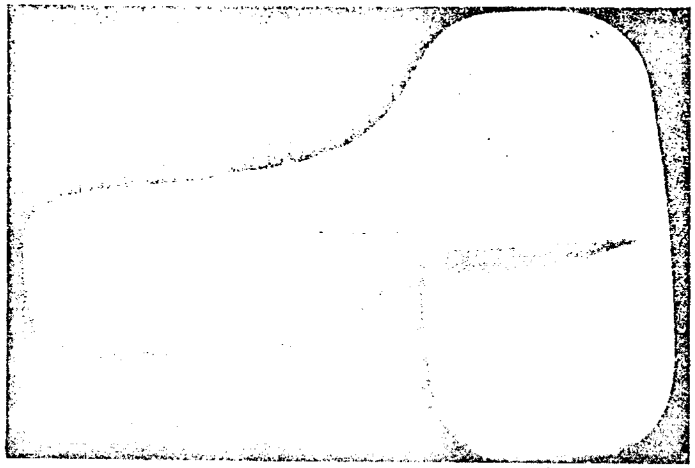


Forging Lap

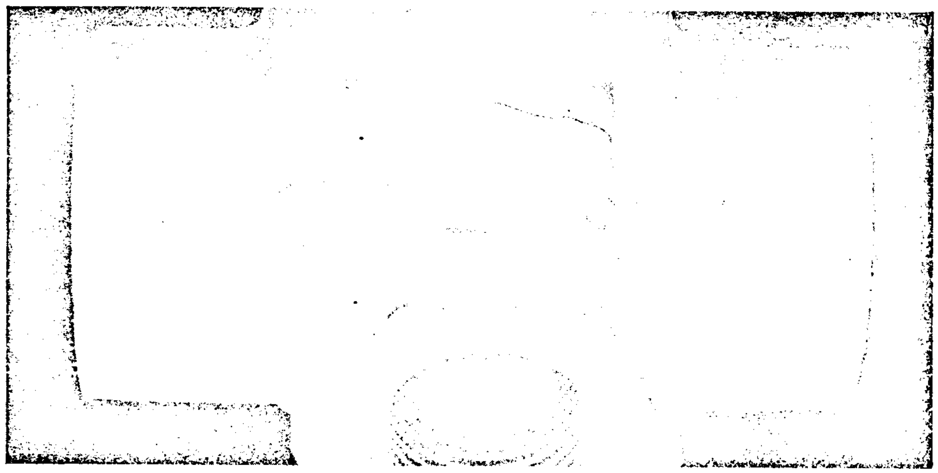
Turn to the next page.

5000040

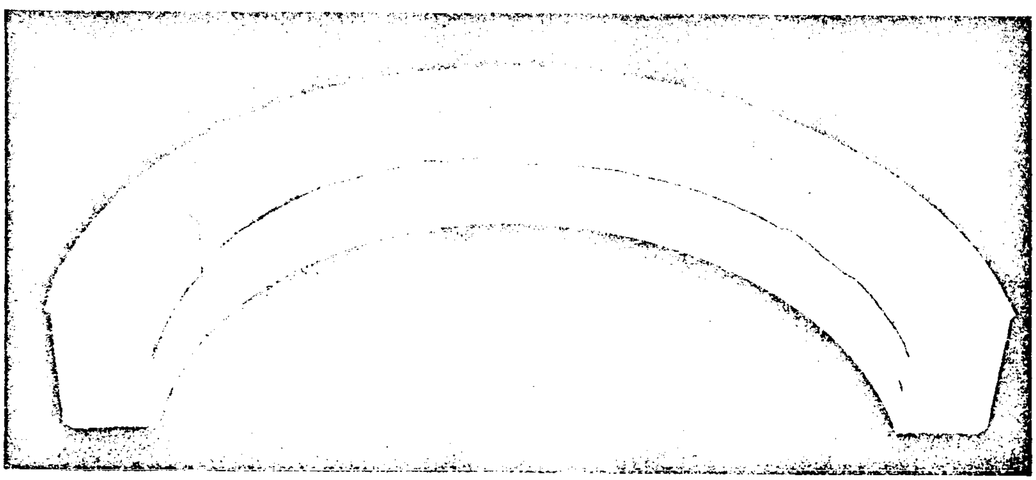
From page 6-4



Forging Lap



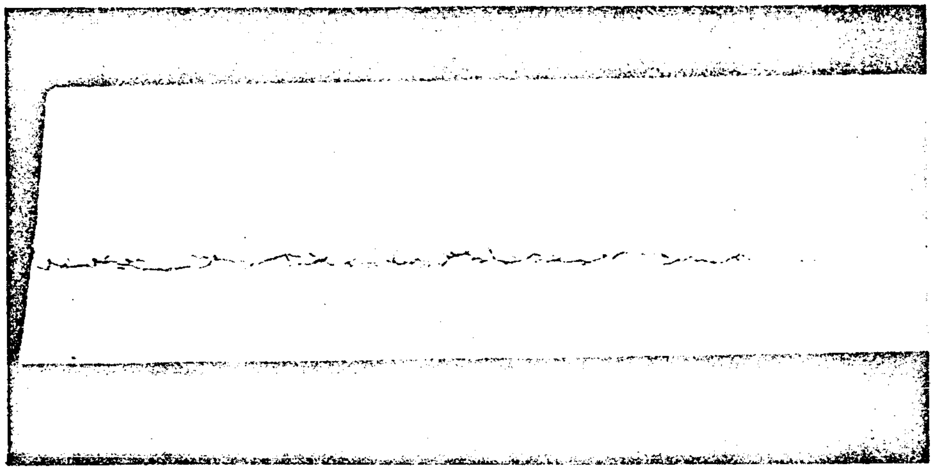
Forging Lap



Lamination

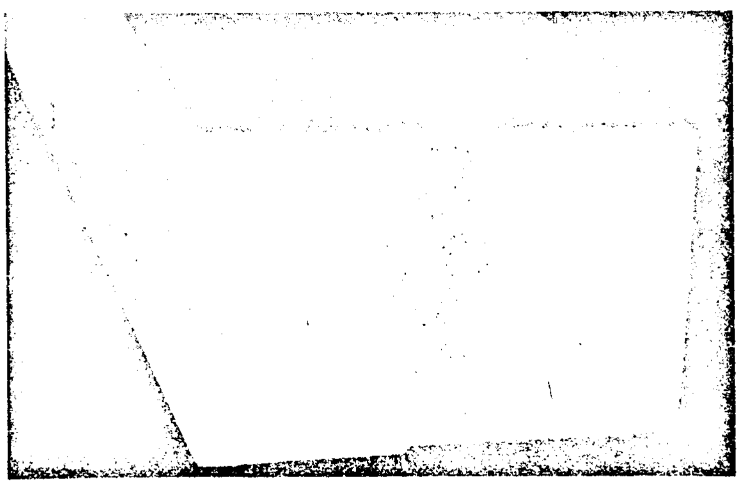
Turn to the next page.

From page 6-5



Weldment Shrink Cracks

Unhealed Porosity in Aluminum Forging

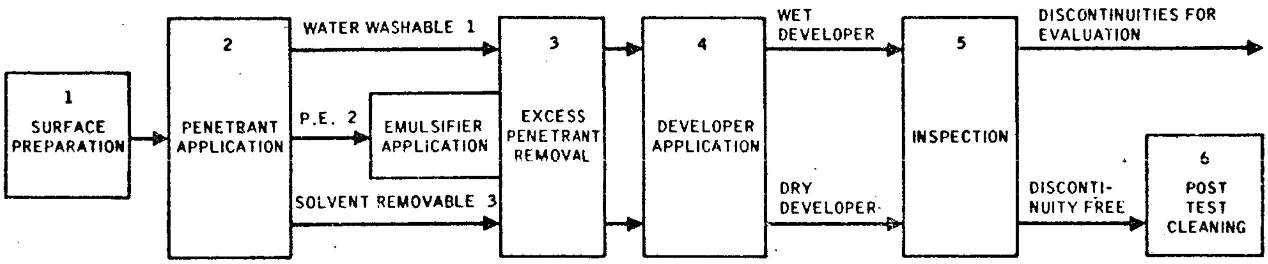


Porosity in 3" Aluminum Plate

Turn to the next page.

From page 6-6

Although Step Five's Inspection might seem to conclude the liquid penetrant process, there are many times one additional step is required. That step is Post-Test Cleaning. It has been added to the flow diagram below as Step Six.



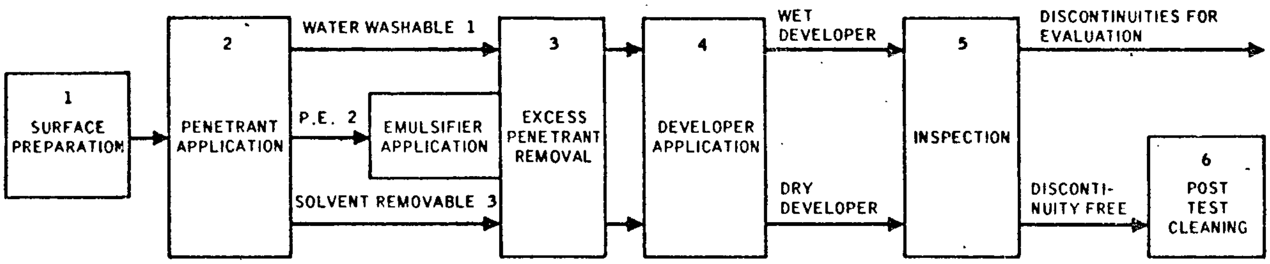
Notice that only those articles, surfaces, weldments, etc., that have been found discontinuity free are directed to Step Six on this flow diagram. This has been done to stress the point that when discontinuities are discovered, they must be evaluated. Naturally this would be done before removing the indications with a post-test cleaning! In fact, after evaluation, Step Six could be eliminated entirely when evaluation determines that the discontinuities present are such that the object inspected is no longer useful and must be scrapped.

When the test article turns up free from discontinuities, however, Step Six may be necessary. This post-test cleaning is quite common and there are many ways it may be done. The methods to be used on each individual job may vary depending upon what is required in the next production activity. For this reason, the post-test cleaning method will be prescribed in the specifications and planning paper with which you've been working. In general, you'll find the same cleaning methods employed in post-test cleaning as used in Step One's "Surface Preparation."

Turn to page 6-8.

From page 6-7

It's time to look over our path, and see where we've been! We've answered questions "WHAT CAN BE LEARNED FROM LIQUID PENETRANT TESTING," and "HOW IT WORKS .... etc." The "MATERIALS NEEDED ..." have been introduced. The Six Steps that have made liquid penetrant testing work have been shown and studied.



Turn to page 6-9.

From page 6-8

1. Step One is ______________ ______________,
   Step Two is ______________ ______________,
   Step Three is ______________ ______________ ______________,
   Step Four is ______________ ______________,
   Step Five is ______________,
And Step Six is ______________ ______________!

2. non-relevant indications

3. When a penetrant test shows indications of press-fitted articles and/or a poor excess penetrant wash, both indications are considered to be ______________ ______________.

4. Excess Penetrant Removal

5. Penetrant indications are formed along the fit lines when articles are press-fitted. They are easily recognized as ______________ ______________, because they look as if they belong.

6. Post-test Cleaning

7. Post-test cleaning is never begun until it has been determined that the article is free of ______________ or that those discontinuities present are not cause for scrapping the article.

1. Surface Preparation
Penetrant Application
Excess Penetrant Removal
Developer Application
Inspection
Post-Test Cleaning

2. When conducting Step Five the tester must be on the lookout for indications that are — for testing purposes — meaningless! In liquid penetrant testing such indications are called non-__________ __________.

Return to page 6-9, frame 3.

3. non-relevant indications

4. A non-relevant indication that appeared as large splotches of penetrant would indicate that Step 3, ________ ________ ________, has been poorly done.

Return to page 6-9, frame 5.

5. non-relevant indications

6. Step Six is ______________ ______________, and is not always needed.

Return to page 6-9, frame 7.

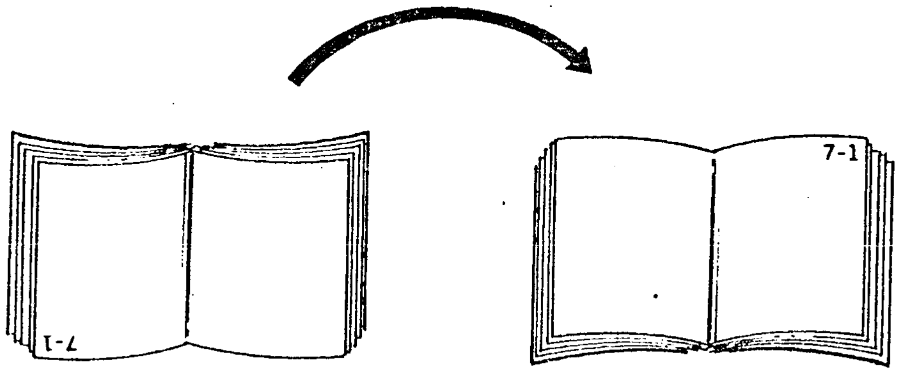
7. discontinuities

8. Now turn to page 6-11.

From page 6-10

Now you are ready to start back through the book and read those upside-down pages.

TURN OR ROTATE THE BOOK 180° - LIKE THIS



READ PAGE 7-1 AND CONTINUE AS BEFORE.

Only one question remains unanswered — WHAT ARE THE LIMITATIONS OF LIQUID PENETRANT TESTING? Let's see what they are.

When you get right down to it, this testing process we've been discussing has, for all practicable purposes, only one limitation: The discontinuities sought must be open to the surface!

However, this doesn't mean that liquid penetrant testing is always used when you are looking for these discontinuites open to the surface. In two situations there is definitely a better choice, and liquid penetrant testing generally becomes second choice if it is used at all!

Here are the two situations where other testing methods have proved better able to handle the job.

1. When it is necessary to examine ferromagnetic material.
2. When the surface you must examine is extremely porous.

Let's take these situations one at a time. But first — before we see what method is first choice for ferromagnetic materials — are you sure you understand what is meant by the term "ferromagnetic"?

No . . . . Page 7-2

Yes . . . . Page 7-3

Before we proceed here's a working definition of the term ferromagnetic.

By definition ferrous means, "pertaining to or derived from iron." So ferrous materials are those materials derived from iron (steel) or of the same family as iron (cobalt and nickel).

Ferromagnetic materials, then, are those ferrous materials which are strongly attracted by magnetism and include the above mentioned metals and their alloys.

Keeping this definition in mind, turn to page 7-3.

From page 7-1

O.K. let's continue.

When testing ferromagnetic material there will be instances when another testing method, such as magnetic particle testing, may be used. Details of the magnetic particle processes will not be covered here. However, one point should be made — magnetic particle testing is not limited to the search for surface discontinuities.

Here's the significance of that statement. After the magnetic particle test has been applied, it is sometimes desirable to use our liquid penetrant test to determine whether a discontinuity detected in the first inspection is, or is not, a surface discontinuity. Liquid penetrant testing will fill the bill because....

...it will show only those discontinuities not already located by magnetic particle testing. . . . . Page 7-4

...it will show only those discontinuities that are open to the surface . . . . . Page 7-5

...it is an older and far more reliable testing method . . . . Page 7-6

Here's a point we may not have stressed strongly enough. A magnetic particle test is not limited to detection of surface discontinuities (as is the liquid penetrant inspection). It will <u>also</u> show areas where sub-surface discontinuities exist. Note carefully the underlined word "also" in the preceding sentence. It's a reminder that the magnetic particle process will show both surface and sub-surface discontinuities.

Return to page 7-3, and give it another try.

From page 7-3

Exactly! If our second carefully conducted test, this time with liquid penetrant, came up with a blank, the discontinuities located by magnetic particle tests would be known to be under the surface.

The second situation where our liquid penetrant test is apt to be no more than a second choice occurs when the surface that needs examination is considered extremely porous. In this case, as before, liquid penetrant testing will work but there is a better method. It is called the Filtered Particle Test. Its name gives us a clue to the peculiarities which make it first choice. Keep this name in mind as we examine the problem faced in testing porous surfaces.

First of all, a porous surface is full of small cavities that will hold liquids. When such a surface is undesirable, it becomes a discontinuity called. . .

. . . an inclusion . . . . Page 7-7

. . . porosity . . . . Page 7-8

. . . a cold shut . . . . Page 7-10

From page 7-3

Your answer: "...it (liquid penetrant testing) is an older and far more reliable testing method (than magnetic particle testing)."

You are going to be directed to try that last batch of questions again. When you state that you feel our liquid penetrant testing is an older method, you are correct. We can't honestly state, however, that it is a far more reliable testing method than magnetic particle testing. However, one of the selections on page 7-3 does state a very sound reason for using our liquid penetrant test after a magnetic particle test has been completed.

Turn to page 7-3, and select one of the other choices.

From page 7-5

An inclusion is described as a particle of foreign material that has been caught in the hardening of metal into an ingot state. Inclusions are always sub-surface unless they have been machine cut and exposed to the surface. This is not common, but even a surface that reveals inclusions will not be one that is full of small cavities "that will hold liquids," a surface described as porous. Your answer was not correct.

Look again for a name that could be used to describe such a surface from among those offered on page 7-5.

From page 7-5

Good. When unwanted, such a porous condition is called porosity and is a surface discontinuity sought with the liquid penetrant method. However, in such things as unfired ceramics, porosity is the normal condition. In these materials, the porous surface is accepted, even desirable, and....is definitely not a discontinuity!

These normally porous materials, however, don't escape nondestructive testing. They are still subject to flaws and must be checked for those things that are considered discontinuities. A crack, for example, can be just as damaging in a porous ceramic insulator as it is in a non-porous plastic garden hose. If the insulator is to be examined, indications of cracks would be sought; indication of its porous nature (or porosity) would not. The liquid penetrant testing procedures we've been studying wculd reveal both conditions. In a liquid penetrant test, indications of a porous nature are often so strong other discontinuities may be overwhelmed and remain undetected.

With porous materials, a test method is needed which will not show porosity but which will show cracks and other legitimate discontinuities. Filtered particle tests will accomplish this objective.

Turn to the next page.

From page 7-8

Filtered particle testing is similar to liquid penetrant testing. However, instead of fluorescent or visible dyes held suspended in a liquid penetrant, small particles are found in the penetrant liquid. Interestingly enough, in industrial use these particles are themselves fluorescent. When testing a porous surface with filtered particles, you will find that all of the liquid penetrant will be absorbed. There will be no "excess" requiring removal (as in our liquid penetrant processes). Where a discontinuity such as a crack is present a peculiar phenomenom occurs which provides us with indications of the crack. The increased area created by a crack (its walls, etc.) will cause more of the penetrant to be absorbed there than elsewhere. The crack will "filter" the penetrant leaving the particles on the surface. Since more penetrant will be absorbed there, a greater buildup of particles will be found at the site of this crack. This buildup of fluorescent particles will provide a visual indication of discontinuities open to the surface.

Therefore, is the following statement true or false?

Liquid penetrant testing must never be used on a porous surface.

True . . . . Page 7-11

False . . . . Page 7-12

From page 7-5

A cold shut is described as an imperfect joining of two metals, as when casting and chilling prevents one stream of metal from fusing with another stream in the same mold. The result is seen as a crack-like discontinuity called a cold shut. It is not a surface that can be described as "full of small cavities which will hold a liquid." Such a surface is considered porous and is called by another term than cold shut. The term is listed among the choices on page 7-5. See if you can spot it now.

From page 7-9

Looks as if we've understated liquid penetrant's role and overstated the role of filtered particle testing when a porous surface must be inspected. We did not mean to imply that liquid penetrant testing <u>cannot</u> be used on a porous surface. All that was intended was to inform you that liquid penetrant is second choice when testing a porous surface.

Turn directly to page 7-12 for a last look at the one real limitation we face.

Good for you!

There is only one limitation for our liquid penetrant tests. The method can be used on ferromagnetic materials. It can be used on porous surfaces.

Its limitation? The discontinuity must be open to the surface.

With this background in liquid penetrant testing you're ready for our final short review of the liquid penetrant process.

Turn to the next page.

From page 7-12

1. When you consider the liquid penetrant process in its entirety, you can see that it has only one limitation; the discontinuity sought must be __________ __________ __________ __________.

2. filtered

3. And when ferromagnetic materials are tested, a method that will show sub-surface as well as surface discontinuities is commonly chosen instead of liquid penetrant testing. This non-destructive testing method is called __________ particle testing.

4. sub-surface

5. From this you can see that it is often worthwhile to <u>use</u> liquid penetrant tests in combination with other nondestructive tests. This ends the review of Chapter 7. For more on the use of liquid penetrant testing, please turn to the next Chapter.

1. open to the surface

2. Even though liquid penetrant testing has but one limitation — the discontinuity sought must be open to the surface — it is not always the first method chosen in every situation. For example, when a surface is quite porous in structure a non-destructive testing method called ________ particle testing is generally first choice.

Return to page 7-13, frame 3.

3. magnetic

4. When a magnetic particle test produces indications of discontinuities that do not appear when the same article is then subjected to a liquid penetrant test, the discontinuities would be known to be ______________!

Return to page 7-13, frame 5.

In this, the second part of this program, you'll be supplying answers to questions which arise in typical situations requiring nondestructive testing with liquid penetrant. In supplying those answers, you'll be applying the proper penetrant from among the three presented in the preceding chapters!

1. Water-Washable
2. Post-Emulsification (P.E.)
3. Solvent-Removable

You will be applying the proper dye from the two types available:

1. Fluorescent
2. Visible

And, you'll be applying the proper developer of the two introduced in the preceding chapters:

1. Wet developer
2. Dry developer

The combination of materials used — dye penetrant, and developer — will describe the liquid penetrant process for any given test. As each process is applied, the reason for its choice will be discussed, and the action you must take will be reviewed.

Please turn to the next page!

Here are the processes available for liquid penetrant testing. Notice that PENETRANT/DEVELOPER combinations.

1. Fluorescent, water-washable penetrant/water based wet developer
2. Fluorescent, water-washable penetrant/non aqueous wet developer
3. Fluorescent, water-washable penetrant/dry developer
4. Fluorescent, post-emulsification penetrant/water based wet developer
5. Fluorescent post-emulsification penetrant/non aqueous wet developer
6. Fluorescent, post-emulsification penetrant/dry developer
7. Fluorescent, solvent-removable penetrant/non aqueous wet developer
8. Visible-dye, water-washable penetrant/water based wet developer
9. Visible-dye, water-washable penetrant/non aqueous wet developer
10. Visible-dye, post-emulsification penetrant/water based wet developer
11. Visible-dye, post-emulsification penetrant/non aqueous wet developer
12. Visible-dye, solvent-removable penetrant/non aqueous wet developer

Looking back over these 12 liquid penetrant processes, you can see that each process is rather self-descriptive. For example, you'll find that the type of dye required will be included in the process description. Either the word "Fluorescent" or "Visible-Dye" will always be in evidence. What is your judgment of the following statement; is it true or false?

The type of lighting needed in a liquid penetrant test will be indicated by the process description.

True . . . . Page 8-3

False . . . . Page 8-4

From page 8-2

True is correct.

And, furthermore, you find a quick reminder of how to go about conducting your dye-penetrant test in the process description too!

For example, if the process description includes the term "flourescent" instead of "visible dye", you know that you'll be using black light as follows:

During Steps Three and Four . . . . Page 8-5

During Steps Two and Five. . . . . Page 8-6

During Steps Three and Five . . . . Page 8-7

From page 8-2

Here's our statement again. "The type of lighting needed in a liquid penetrant test will be indicated by the process description."

Although you judged this a false statement, it really is true.

Look at it this way, you know that when fluorescent dyes are used they'll be seen as a yellow-green glow if you view them under black light. That tells you that you'll be needing the special lighting set-up that produces black light if you use fluorescent penetrants.

And, are you given any idea of the type lighting required when the process you plan to use will require the use of visible dyes? You bet! You know that visible dyes are simple, bright colored dyes that you can easily see with ordinary daylight or which will be visible in artificial light.

You can now see that your choice could have easily been true. O.K. ? Turn to page 8-3.

It looks as if a review of the steps outlined in the previous chapters is in order. Here they are:

Step One - Surface Preparation

Step Two - Penetrant Application

Step Three - Excess Penetrant Removal

Step Four - Developer Application

Step Five - Inspection

Step Six - Post-Test Cleaning

You've stated by your answer that you'd expect to use the black light during Step Three and Step Four. You are partially correct. During Step Three's excess penetrant removal you will be using the water-wash, and with fluorescent dyes washing under black light is recommended. There is no place for black light use during developer application, however. With the review of the steps above, you'll have no difficulty locating an answer that provides two ideal places for use of black light.

Return to page 8-3 and give it another try.

From page 8-3

Your answer, "During Steps Two and Five, " is only partially correct. Black light is used during Step Five, alright! That's the point in the test of the article when our efforts should bear fruit. Step Two, however, is penetrant application. It would be difficult to apply penetrant in the darkened area necessary for black light use. But black light will come in handy when removing excess penetrant.

Turn to page 8-3 and select a more completely correct answer.

From page 8-3

Fine! If you got here on your first pick, you must have the steps mentioned in previous chapters down pat. In Step Three (excess penetrant removal) your chances for an adequate wash are definitely improved if the washing is done under black light. And when you look for evidence of discontinuities in Step Five, you wouldn't have much luck without the black light that fluorescent dyes require.

The point to remember here is this. If you get stuck, or are puzzled at any time during your work with liquid penetrant testing, stop and take a long look at the words used to describe the process you want to use. It can tell you quite a bit, and might just solve your problem.

Here are the 12 processes you'll be using, why not look them over again right now. Keep in mind the help they can provide.

1. Fluorescent, water-washable penetrant/water based wet developer
2. Fluorescent, water-washable penetrant/non aqueous wet developer
3. Fluorescent, water-washable penetrant/dry developer
4. Fluorescent, post-emulsification penetrant/water based wet developer
5. Fluorescent, post-emulsification penetrant/non aqueous wet developer
6. Fluorescent, post-emulsification penetrant/dry developer
7. Fluorescent, solvent-removable penetrant/non aqueous wet developer
8. Visible-dye, water washable penetrant/water based wet developer
9. Visible-dye, water washable penetrant/non aqueous wet developer
10. Visible-dye, post-emulsification penetrant/water based wet developer
11. Visible-dye, post-emulsification penetrant/non aqueous wet developer
12. Visible-dye, solvent removable penetrant/non aqueous wet developer

Turn to the next page.

All of the 12 processes have one of the following in common. Do you know which it is?

All require use of a water wash at 110°F . . . . Page 8-9

All require cleaning of the article before penetrant application . . . . Page 8-10

All require dryer use . . . . Page 8-11

Think about your answer again, it was not entirely correct. You've stated that all 12 processes used in liquid penetrant have this in common: all require use of water wash at 110°F. But, remember not all will require the use of water for excess penetrant removal. Solvent-removable penetrants require the use of solvent. However, water is the method used with water-washable penetrants, and you are correct on the temperature maximum. When a water wash is used, the water temperature should not exceed 110°F.

Please return to page 8-8, and look over the selections again, and choose another answer.

Good enough! Each process certainly does require cleaning prior to penetrant application. What else is disclosed with penetrant identification? Well, take another look at two of the penetrants...

...water-washable; and post-emulsification.

"Water-washable" tells us a whole lot more than just the fact that excess penetrant is removed with water. And "post-emulsification" implies more than the requirement of an additional step!

Water-washable penetrant is particularly valuable for testing parts having rough surfaces or parts which contain keyways or threading. You'll know why from your reading in previous chapters.

One of the following states the reason pretty well.

The penetrant's composition makes it easily washed .... Page 8-12

The penetrant itself contains solvents to clean out surface contaminants in rough surfaces .... Page 8-13

From page 8-8

Hold on a minute. Dryer use is not always required. We can't say that all six of the liquid penetrant processes will require the use of the dryer. The dryer is used, when possible, to speed up the drying process. But it is not required and, as on large articles, could not be used in all instances.

With this in mind, return to page 8-8 and try again.

From page 8-10

Fine. You are definitely on the right track!

Water-washable penetrant has what can be thought of as a "built-in" emulsifier that speeds up the process — makes it easy to wash away excess penetrant from rough surfaces.

The advantage of having a "built-in" emulsifier becomes a disadvantage when we face a somewhat different situation, a situation expressed in one of the statements below.

Water-washable penetrant requires an "extra step" in the process before penetrant removal . . . . Page 8-14

Water-washable penetrant is not satisfactory for shallow discontinuity detection because of its built-in emulsifier . . . . Page 8-15

Water-washable penetrant is not good for use on rough surfaces because of its emulsifying agent . . . . Page 8-16

From page 8-10

Your answer: "The penetrant itself contains solvents to clean out surface contaminants in rough surfaces."

Water-washable penetrant is particularly valuable for testing articles having rough surfaces, etc., but does not have any "solvents" in it designed to clean away surface contaminants. Nor does post-emulsification penetrant. Water-washable penetrant is used on these rough surfaces. The reason it is, is mentioned in one of the other statements on page 8-10.

Return to that page now, re-read it, and then choose again.

From page 8-12

Let us clear up one point right now! It is post-emulsification penetrant that requires the "extra step" not water-washable penetrant. Water-washable has what can be thought of as a "built-in" emulsifier. The addition of the emulsifier is the extra step mentioned in the answer you selected. Why is it used? To make the post-emulsification penetrant excess removable with water. But, why isn't water-washable penetrant used in the first place? Because carefully-used, post-emulsification penetrant is much more satisfactory for use when checking for shallow discontinuities.

Please return to page 8-12 and select another answer.

5000CBP

From page 8-12

Right again! You are demonstrating a grasp of the material presented in previous chapters. The water-washable penetrant has a major limitation; its built-in emulsifier makes it too easily removed from shallow, scratch-like discontinuities. Therefore, it is unwise to use this penetrant when you are interested in detecting discontinuities of this nature. One of the other penetrants is better suited for this job. It is ....

The solvent-removable penetrant .... Page 8-17

The post-emulsification penetrant .... Page 8-18

We goofed it! Your answer was not correct and it tells us we should stress our point again.

Water-washable penetrant has a "built-in" emulsifier that speeds up the liquid penetrant process and makes it easy to wash away excess penetrant from rough surfaces.

Since it washes easily from rough surfaces, how will it work on surfaces we want to inspect for shallow discontinuities? With this question in mind, return to page 8-12 and take another crack at the selections listed there.

From page 8-15

You have indicated that, given a choice between post-emulsification and solvent-removable penetrants, you'd choose the latter.

It is not the answer we'd hoped you'd select. But we can't say that you are entirely wrong. There are many situations when it will be specified that solvent-removable penetrants be used and their excess be removed with a solvent designed for that purpose. There can be many reasons for this. The greater mobility provided by solvent-removable penetrants may require their use. The need to prevent using water-based materials on the article might likewise demand them. But, in our example, we made no specific mention of any special consideration.

We wanted to stress the advantage found in using the extra step requiring P. E. penetrant. It is more reliable for use when shallow discontinuities are sought because, with careful control of the emulsifier, penetrant will remain in these discontinuities during wash.

Return to page 8-15 and select the other answer.

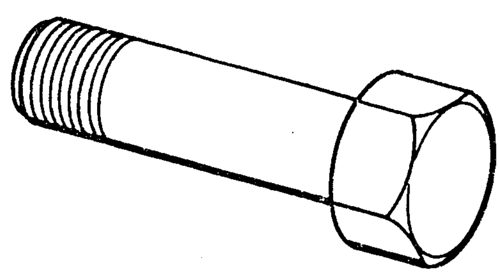
From page 8-15

Excellent! Chalk-up another correct one. Selecting the post-emulsification process would be a good move. Its extra step permits reliable inspection for shallow discontinuities, but there's a price to pay for its safeguard. Items with blind holes, threads, or keyways, present a problem. It is very difficult to determine the correct emulsification timing.

Too little time and you will have poorly emulsified penetrant in a hard-to-reach location. The result: excess penetrant may not be removed from those areas during the wash.

If you allow enough time for penetrant to emulsify in these blind holes, etc., penetrant will also emulsify in the shallow surface discontinuities you seek. The result? Unreliable discontinuity indications as shallow discontinuity indications are lost.

Therefore, which of the two fluorescent penetrants would you select to examine this bolt.....

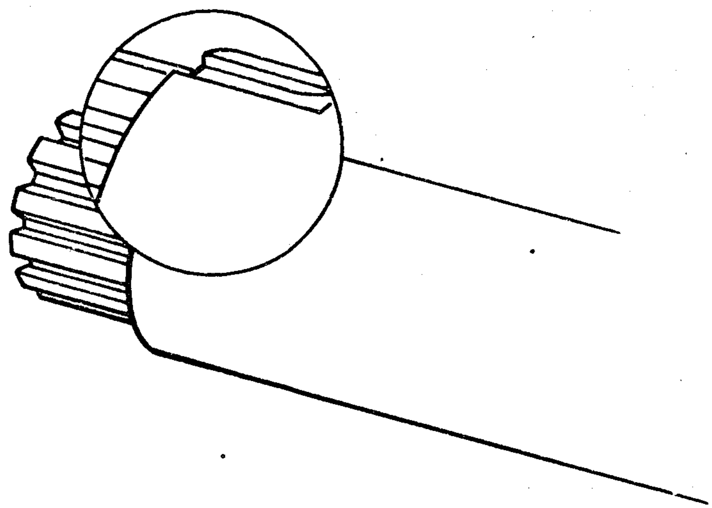


Water-washable . . . . Page 8-19

P.E. . . . . Page 8-20

Water-Washable.

Fine! And which for this keyway?



Water-Washable . . . . Page 8-21

P.E. . . . . Page 8-22

From page 8-18

Ooops!

You know that water-washable is preferred for use when articles are rough surfaced or contain threads or keyways. The bolt has threads.

Come on now, you'd use water-washable, wouldn't you?

Turn to page 8-19

Good for you. Water-washable should be used instead of post-emulsification for testing articles with blind holes, threading, or <u>keyways</u>.

Let's take a look at the third penetrant — solvent-removable. It must not be forgotten. Solvent-removable penetrant has characteristics which make it especially attractive for some penetrant testing jobs.

Perhaps the most important characteristic of solvent-removable penetrant is that it can be used outdoors without using heavy complex equipment. It is excellent for many maintenance inspections and for the required examination of such items as weldments on large assemblies near completion.

Here's a chance to put one of the penetrants to work. If you were called upon to examine sixty, 300-series, stainless steel screws, each 1/4 by 1-1/2 inches with rolled threads, which one of the following penetrants would you choose?

Water-washable . . . . Page 8-23

Post-emulsification . . . . Page 8-24

From page 8-19

Hold on a minute. Your answer was not correct.

Remember, water-washable is preferred for use when articles are rough surfaced or contain threads or keyways. That article shown had a keyway!

Turn to page 8-21

From page 8-21

Right. Water-washable is the best penetrant for use on the sixty, stainless steel screws.

Now that you have the best penetrant for testing the screws, you are ready for Step One — surface preparation. You will want to clean as many of the screws as possible in one operation.

If the following cleaning methods were available to you, which would you select?

Vapor degreasing . . . . Page 8-25
Sandblasting . . . . Page 8-26
Water wash . . . . Page 8-27

From page 8-21

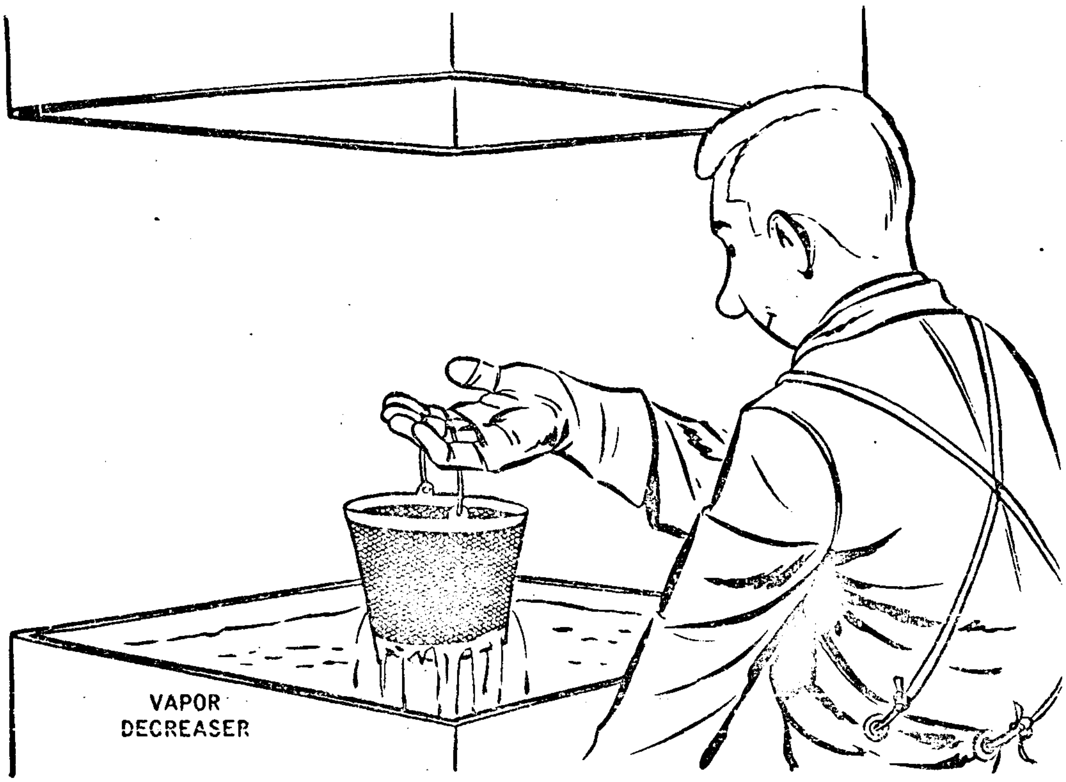
You must have missed the key word "threads" when reading over the description given for the items we want to examine. Here it is again: Sixty, 300-series, stainless steel screws, each 1/4 by 1-1/2 inches with rolled threads.

Remember that water-washable is recommended when you have rough surfaces, threads, or keyways.

For these screws, you'd select water-washable. Right?

Turn to page 8-23.

When using the vapor degreasing process, you would probably place all the screws in a wire basket and dip them in the vapor like this.



When using this or any other chemical cleaning method, you should be as conscious of SAFETY as of cleaning. Why? Because most of the solvents used are ....

...apt to give off poisonous fumes and damage the article .... Page 8-28

...apt to contaminate both the penetrant and the surface .... Page 8-29

...apt to give off toxic and explosive fumes that can irritate the skin ..... Page 8-30

No. You are not correct. Sandblasting is one of the cleaning methods we do not recommend. Why not? Because it is apt to close up discontinuities that would otherwise be open to the surface.

One method that is widely used is listed on page 8-23. Turn to that page and see if you can spot it.

From page 8-23

Water washing is occasionally the only method available for cleaning articles in surface preparation. And, that's about the only time it will be used. Water will not cut through films such as those that oil leaves, etc. When you have the opportunity to use vapor-degreasing to get the screws cleaned, by all means, use it!

Since we are sure you would not choose to use the prohibited sandblasting (the other choice) there is no reason for you to return to page 8-23. You'd use vapor degreasing now, wouldn't you?

Turn to page 8-25 and continue!

From page 8-25

You are partially correct in your answer. The solvents used during cleaning are "apt to give off poisonous fumes" as you have stated. They will not, however, damage the articles. They would not be used if there was that danger. The danger in their use concerns you. The poisonous fumes can make you ill and the damage threat concerns you too. It is this. Most of these chemical solvents used as cleaners will irritate the human skin. They are apt to dry the skin. You should use gloves if possible and have as little skin contact with them as possible.

Please turn to page 8-30, where the program continues.

From page 8-25

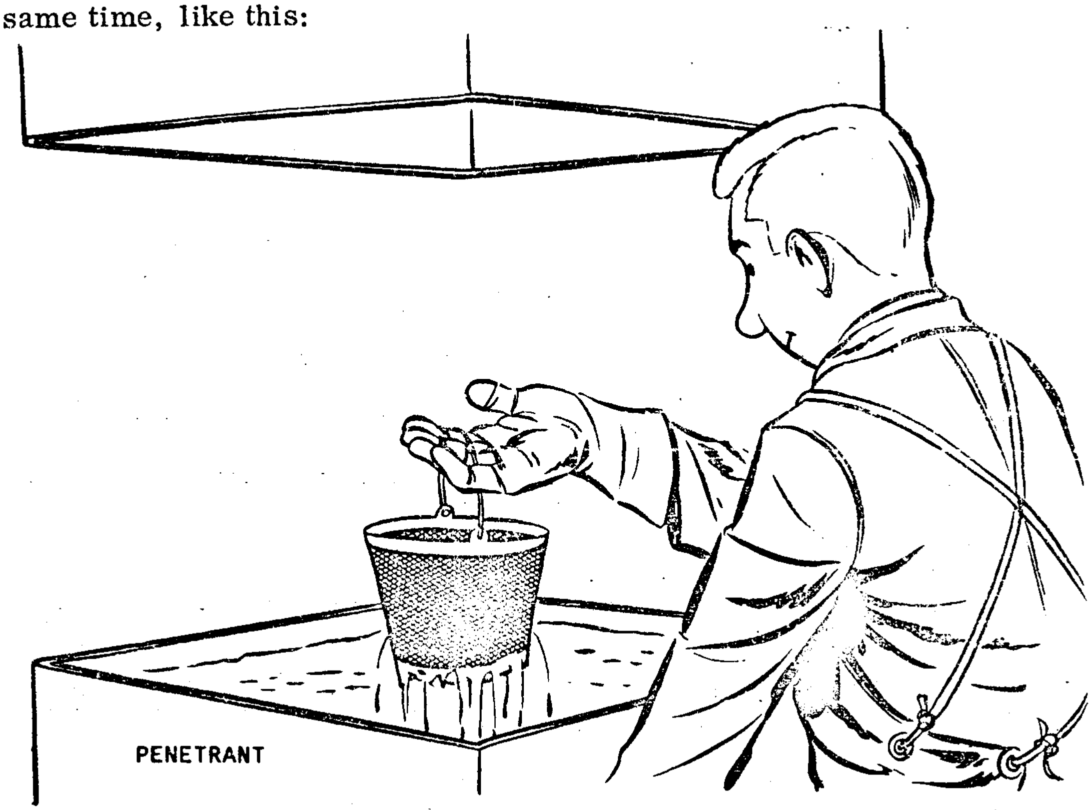
Hold on a minute. When using vapor degreasing, or any other chemical method, you should be as conscious of SAFETY as of cleaning. Why? Well, not as you've answered.

They are being used to remove surface contaminants: oil, dirt, water, rust, scale and the like. And this is being done prior to penetrant application. Unless significant amounts of liquid cleaning material is carried on the article and then mixed with penetrant when dipping the article to apply the penetrant, no penetrant contamination is possible. The safety considerations are for your benefit. Return to page 8-25 and select an answer that best brings you into the picture.

From page 8-25

Good. The old sailor's saying, "One hand for the ship, one for yourself," is appropriate for industry too. But, don't use that "hand-for-yourself" to hold a cigarette while you're working on any phase of a liquid penetrant test. Keep your own safety in mind.

You are now ready for Step Two — application of the penetrant. It can be applied in many ways as you learned in previous chapters. Dipping is a good way to do the job, and it would be ideal for the stainless steel screw. <u>All</u> the penetrant will be applied at the same time, like this:



Continued next page.

From page 8-30

The next problem will be to determine how much time should be allowed for the penetrant to do its job before removing excess penetrant. We have called this the penetration time. To help determine this timing, charts have been prepared; but to effectively use them, three things must be known:

1. Type of penetrant used.
2. Type of material to be examined.
3. Type of discontinuity sought.

You already know two of these three things. One remains to be learned before you have enough information to correctly select penetration time from the charts. It is . . .

. . . the type of penetrant used . . . . Page 8-32

. . . the type of material to be examined . . . . Page 8-33

. . . the type of discontinuity sought . . . . Page 8-34

From page 8-31

We know two of the required three facts necessary to use the penetration time charts successfully. What do we lack? Not as you've suggested... "the type of penetrant used." We have decided to use water-washable penetrant, remember?

Return to page 8-31 and select another.

From page 8-31

Remember now, we are going to conduct a test of sixty, 300-series, stainless steel screws. That tells us what material we'll be examining — stainless steel.

Why not return to page 8-31, and look those other selections over again? One of them contains the missing fact.

From page 8-31

"The type of discontinuity sought" is correct.

If told to seek indications of seams (a common surface discontinuity), we now have the information necessary to use the chart. Just for drill use the chart on this page. See how long a penetrant time is recommended.

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MATERIAL	TYPE OF DISCONTINUITY	PENETRATION TIME
STAINLESS STEEL	SEAMS POROSITY CRACKS	10 MINUTES 5 MINUTES 2 MINUTES
ALUMINUM	SEAMS POROSITY CRACKS	5 MINUTES 3 MINUTES 2 MINUTES
PLASTIC	POROSITY CRACKS	5 MINUTES 3 MINUTES

O.K., what time would you use?

2 minutes . . . . Page 8-35

5 minutes . . . . Page 8-36

10 minutes . . . . Page 8-37

From page 8-34

Nope. Your answer: "Two minutes" is incorrect. Perhaps you reasoned that a crack and a seam are alike. They are not.

APHRODITE COPR. P - 18 - A

MATERIAL	TYPE OF DISCONTINUITY	PENETRATION TIME
STAINLESS STEEL	SEAMS POROSITY CRACKS	10 MINUTES 5 MINUTES 2 MINUTES
ALUMINUM	SEAMS POROSITY CRACKS	5 MINUTES 3 MINUTES 2 MINUTES
PLASTIC	POROSITY CRACKS	5 MINUTES 3 MINUTES

Here's the chart again. The material is stainless steel, and we are looking for seams. The correct penetration time taken from this sample chart is ten minutes. The correct use of the chart for this example is shown by circles drawn around the correct items in the chart above.

Now turn to page 8-37.

From page 8-34

Ooops! Your answer (five minutes) was not correct. You are looking at porosity rather than seams.

Turn back to page 8-34 and check the chart again before choosing another answer.

From page 8-34

Good show. But, remember, caution is recommended during the ten minute penetration time that is required.

CAUTION

Penetrant temperature must be controlled during the minimum penetration times suggested by the chart.

Unless penetration temperatures are maintained within limits, penetration time charts will be unreliable and penetrant may become useless! What penetrant temperature range was recommended to avoid this problem?

32° to 72°F . . . . Page 8-38
110° to 225°F . . . . Page 8-39
50° to 100°F . . . . Page 8-40

From page 8-37

Think about that answer again. We said that penetration temperatures which are too low make the penetrant sluggish. Temperatures below 50°F are too low. Obviously then, a 32°F minimum would be much too low, so your answer — "32° to 72°F" — would be out.

Return to page 8-37 and select the moderate temperature limits which will best allow our penetrant to accomplish its purpose.

From page 8-37

Think back. We need penetrant temperatures with moderate limits to best accomplish our purposes. A range from 110°F to 225°F is not moderate. You were probably thinking of the water-wash maximum temperature of 110°F when you selected this answer.

Remember that articles subjected to penetrants, the temperatures of which are above 100°F, may become uncomfortably hot.

Return to page 8-37 and select another answer.

From page 8-37

Fine, 50°F to 100°F . . . is the proper temperature range for the penetrant. And of course our major concern is with the minimum — 50°F — the sluggish penetrant threat!

Having monitored the penetrant for the correct temperature range, and having allowed for correct penetration time, it's time for the proper wash. This will remove excess penetrant from the surface and is considered Step Three. We'll now capitalize upon the water-washable part of our penetrant. Water will be used to wash off the excess. How would you suggest this be done?

Use a wire basket to hold the screws and quickly dip them
in a tank of water . . . . Page 8-41
Use a coarse, forceful spray . . . . Page 8-42
Brush on a water rinse using brush of the correct size. . . . . Page 8-43

From page 8-40

You have chosen to dip a basket of screws into a tank of water to remove excess penetrant. If you were applying penetrant, or if you were applying developer, this would be a good method. This method could be used to remove excess penetrant but IT IS NOT THE MOST EFFECTIVE METHOD. Penetrant removal has been found most easily accomplished with the aid of a coarse forceful water spray!

Try using a coarse, forceful spray to remove the excess penetrant and turn to page 8-42.

From page 8-40

You are ready for Step Four, application of the developer. Your correct use of a forceful, coarse water spray to remove excess penetrant has made this step possible.

For a developer we have a choice of wet or dry types. What governs the choice? Most will agree the answer to that one is common sense. But, returning to our stainless steel screws, which of the two developers do you think best equipped for the task?

Wet developer (water based). . . . . Page 8-44

Dry developer . . . . Page 8-45

From page 8-40

In answer to our query about washing off excess water-washable penetrant you have stated that you would accomplish this by using a brush. A brush would not prove very effective in the case of the screws and, in any event, is not recommended for use in removing excess penetrant. Bristles might brush some of the penetrant from the discontinuities.

A coarse, forceful water spray is recommended and is effective. Having decided to use this method, you are ready to turn to page 8-42.

From page 8-42

A water based wet developer is correct. This developer is best for use in covering many small items such as the sixty threaded screws.

When using a wet developer, it is not necessary to delay its application until the recently water-washed article dries. The developer contains a white powder in suspension. We want a thin layer of this powder over the surface of each of the stainless steel screws. Dipping these articles in a tank of developer will do the job nicely. The next action will be to use ...

...a drying oven . . . . Page 8-46
...a dry developer . . . . Page 8-47
...black light . . . . Page 8-48

You're here because you chose to select a dry developer for the use on the sixty steel screws. You should be on page 8-44. Why?

Picture those sixty steel screws lying in that basket. They are haphazardly jumbled together. It would be impractical to use a dry developer. It could not be applied evenly to each screw. The solution is to use a wet developer. Since this is now your choice, turn to page 8-44 and continue.

From page 8-44

Yes! We would probably use a drying oven next. It would be used to speed the evaporation of the water part of the wet developer. Assuming that a lower limit does not apply, care must be taken not to use a dryer temperature of more than 225°F. Why?

Because higher temperatures can cause wet developer evaporation ...... Page 8-49

Because higher temperatures will cause dye-penetrant evaporation from the developer.................................... Page 8-50

From page 8-44

You chose to apply a dry developer as the action following application of a wet developer. They both accomplish the same thing — a layer of powder over the surface of the article. There certainly would be no point in applying two developers. And besides, the screws are wet, a dry developer cannot be used on wet articles.

A clue to the action to be taken after application of the wet developer should be in the word "wet". Return to page 8-44 and select another answer.

From page 8-44

Your choice — "black light" — indicates that you are getting a little over-anxious for the payoff. Before using a black light, you have to have a fluorescent penetrant and ALLOW FOR SUFFICIENT DEVELOPMENT TIME, or else you will not be able to see the yellow-green discontinuity indications.

The clue to your next step is in the word "wet." Return to page 8-44 and select the step required after application of the wet developer.

From page 8-46

The question was: "Assuming that a lower limit does not apply, care must be taken not to use a dryer temperature of more than 225° F. Why?" Your selection was: "Because higher temperatures can cause wet developer evaporation."

Although care certainly must be taken not to exceed a dryer temperature of more than 225° F, wet developer evaporation is not the reason. You <u>want</u> the water in the wet developer to evaporate, leaving a thin covering of powder.

Consider the question carefully, return to page 8-46 and select the correct answer.

From page 8-46

Good for you. That's the point we hoped to make.

Dryer temperatures above 225°F are apt to cause penetrant evaporation from the developer preventing the spread of the penetrant through the developer.

Our basket of screws will remain in the oven until development time is complete. Remember, development time is considered to be the time from developer application until the article is ready for testing. (This would include the time in which the articles are in the drying oven.) In previous chapters, a guide was mentioned for determining this total development time. Remember what it was?

Our guide will be the developer time charts found in the testing area . . Page 8-51

Our guide will be experimentation using samples containing the type of discontinuity we seek . . . . Page 8-52

Our guide will be one-half the penetration time . . . . Page 8-53

595596

You chose the statement: ". . . . will be the developer time charts. . . . "

In selecting this answer you are probably remembering the penetration time charts mentioned earlier; there are no charts for determining development time. A rule of thumb, which has been mentioned, will have to be our guide in development.

Return to page 8-50 and select the guide which was stated earlier as a rule of thumb.

Experimentation is used in determining emulsification time, NOT IN DETERMINING TOTAL DEVELOPMENT TIME. It is probable that you were remembering this experimentation when you selected your answer. To determine development time, however, we must use something a little less scientific — a rule of thumb.

This rule was given to you earlier in the program. Return to page 8-50 and see if you can spot it.

Good thinking. Our guide for development time will be the rule of thumb: "Use half the penetrant time."

When this time period has elapsed, indications of any discontinuities present will be visible (when the screws are subjected to black light if fluorescent penetrant was used; in normal lighting if visible-dye penetrant was used).

If you are using a fluorescent penetrant and you've just popped into the black light booth your eyes must be given a minute or two to adjust to the dark before you'll be able to see all of the discontinuities clearly. Black light is not visible to a significant degree, and if you look directly at the light source your vision will become fuzzy. Look away for a few seconds and everything will be clear again. Black light is not ultraviolet. It is harmless!

Turn to the next page and we'll tackle a couple of other typical inspection situations.

From page 8-53

In which of the following situations would you choose to use post-emulsification penetrant?

Precision castings for shallow discontinuities . . . . Page 8-55

A weldment for shrink cracks . . . . Page 8-56

From page 8-54

Excellent! The clue is ". . . . shallow discontinuities." P.E. penetrant will fill the bill nicely. It will allow a close check for it serves particularly well in detecting shallow discontinuities.

Which of the following will represent your course of action when handling these precision castings with post-emulsification penetrant?

I

1. Prepare surface
   a. Clean article
2. Apply penetrant
   a. Dry article
   b. Apply emulsifier
3. Wash article

Page . . . 8-57

II

1. Clean article
2. Apply penetrant
   a. Apply emulsifier
3. Remove emulsifier
   a. Dry article

Page . . . 8-58

III

1. Prepare surface
   a. Clean article
2. Apply penetrant
   a. Apply emulsifier
3. Remove excess penetrant

Page . . . 8-59

Turn to the page number at the bottom of the listing you have selected.

From page 8-54

You have selected to examine a weldment for shrink cracks with post-emulsification penetrant.

We feel that you would have better luck with this penetrant if you had chosen to use it on the precision castings where you were requested to check for shallow discontinuities. The P. E. penetrant is especially designed for detecting shallow discontinuities, such as we seek in the precision castings, but it is not suggested for use on relatively rough surfaces. Weldments are often considered rough and post-emulsification penetrants are denied them.

Of course, which penetrant you use may depend upon what's available to you, or required by contract. But for the purposes of this program, assume post-emulsification penetrant is available for use on the precision castings. It will make your job of testing them easier. Let's get to it.

Turn to page 8-55 and we'll continue.

From page 8-55

You have selected the following sequence for applying the P. E. penetrant process to precision castings.

1. Prepare surface
   a. Clean article
2. Apply penetrant
   a. Dry article ← incorrect
   b. Apply emulsifier
3. Wash article

It was not correct for the following reasons. Notice that in number 2 above (apply penetrant) the next action is to dry the article. This is not the case. Prior to penetrant application the article may have been dried as a part of surface preparation if water contaminants were present. But, the next action after the application of the penetrant will be the application of the emulsifier. This in turn will be followed by the water wash used to remove the penetrant excess.

Return to page 8-55 and choose a sequence that better represents the P. E. penetrant requirements.

The following was your choice representing the sequence of actions necessary when P.E. penetrant is used on the precision casting.

1. Clean article
2. Apply penetrant
   a. Apply emulsifier
3. Remove emulsifier ←— incorrect
   a. Dry article

Your choice was not correct. Step 1, the first action, was better represented with...

1. Prepare surface
   a. Clean article,. . . but we have no real quarrel with your choice in this first action.

However, you've chosen to remove the emulsifier as Step Three and then dry the article. The emulsifier is allowed to mix with the penetrant excess for the proper time, in real practice. It is then that the penetrant excess is removed in Step Three. If a dry developer will be used in Step Four, your next action was correct .... the article would be dried. If, however, we decide to use a water-based wet developer, it will be applied next; prior to dryer use.

There is a better listing of the necessary sequence of actions on page 8-55. Please return to that page and select it.

You have chosen the proper sequence for the actions necessary when post-emulsification penetrant is used.

You are probably aware that the most critical part of a test using P. E. penetrant will be the timing of the emulsification period. Proper timing here is more vital to testing success than timing of penetrant and developer periods. Can you remember how the proper emulsification time period is determined?

Prepared Charts . . . . Page 8-60

Rule of Thumb . . . . Page 8-61

Experimentation . . . . Page 8-62

You'd be very lucky if your answer is correct! You've stated that you would be able to determine the proper emulsification time period from prepared charts. This is seldom possible. There are prepared charts for penetration times. They are usually supplied by the penetrant manufacturer. There are no charts supplied by the emulsifier manufacturer. There are so many variables that the emulsification times needed must be determined for each different test situation. For example, if you were planning to use the P. E. penetrants on a series of six-inch aluminum flanges, you would first need to know what type of discontinuity you must locate. When this was known, you'd need an article with these discontinuities. This article would then be subjected to liquid penetrant testing using P. E. penetrant, and various different emulsification times would be tried. The time that best showed the discontinuities you know exist would be accepted as the proper emulsification time. You can see why we feel you are lucky if you have a chart giving you these times. It means that someone else has conducted the tests necessary to give you the emulsification time necessary for your particular task.

The process used to find the correct emulsification time is well named by the correct answer on page 8-59. Turn to that page now, and see if you can tell which it is!

Your answer indicates that you feel emulsification times are determined by . . . "rule of thumb." Evidently we have confused the issue!

A "rule of thumb" was mentioned in this program, but not for determining emulsification times. It is used to determine the development time. And that rule is as follows: Use one half the penetrant time for the development time.

The penetrant time, as you probably remember, is easily determined. It will be determined from prepared penetration time charts, usually supplied by the penetrant manufacturer.

But, emulsification times are a "horse of a different color." These must be determined individually for each and every different testing situation. For example, if you were planning to test a series of aluminum filler caps, you'd first need to know what type of discontinuities you must locate. When this was known, you'd need an article known to have these discontinuities. Then this article would be subjected to liquid penetrant test, using P.E. penetrant of course, and various emulsification times would be tried. The time at which the discontinuities you know to exist became most clearly visible would be accepted as the proper emulsification time for use in your examination of these particular filler caps.

The process used to determine this time is well named by the correct selection on page 8-59. Return to that page and pick it out!

From page 8-59

Experimentation is correct. It would be easier for all of us if a less time consuming method than experimentation were possible for determining the emulsification period. But, this is not the case. When post-emulsification penetrant is selected, the proper emulsification period must be determined for each testing situation faced.

An article will be provided containing known examples of the type discontinuity we must locate. This article will be a guinea pig; in several tests emulsifier will be applied to it and left on it for varying time periods for each test. Each test will be carefully monitored. The elapsed time between application of the emulsifier and the specific washing which has the best results, will be the proper emulsification time for that particular testing situation.

One method of applying this emulsifier was prohibited. Remember it?

Never apply emulsifier by dipping . . . . Page 8-63

Never apply emulsifier by spraying . . . . Page 8-64

Never apply emulsifier by brushing . . . . Page 8-65

"Never apply emulsifier by dipping" was your answer. However, dipping is not a prohibited method for applying the emulsifier. Your answer is not correct. Why this is so can best be explained by considering once again why we are using P. E. penetrant — a penetrant that requires a time consuming extra "step." It is this extra step that will make the penetrant water washable. We have avoided this to the last moment, and carefully controlled the process because we fear that the penetrant will be mistakenly removed from shallow discontinuities. When we have to test articles for such discontinuities we are apt to use P. E. penetrants to do the job. However, if we are not careful in applying the emulsifier we could scrape away some of the penetrant, and lose the advantage we've gained in conducting the extra step.

Return to page 8-62 and look again at the selections. One of them could result in scraping away some of that penetrant. It is the forbidden application method. See if you can spot it.

From page 8-62

Hold on a minute. There is no danger to our penetrant test if the emulsifier is sprayed on. (Your answer has indicated you feel there is.) On the contrary, this is an acceptable, and often used, method.

Look at the situation again. We have used post-emulsification penetrant because we want to make sure we do not miss any shallow surface discontinuities. Using water-washable penetrant we run the risk that penetrant will be too easily washed away from these shallow discontinuities. It stands to reason then, that we must be just as concerned with the possibility of removing penetrant from these areas by any other means — such as scraping, for example. If we were to apply our emulsifier by a means that could do that, we would certainly run the risk of missing the shallow discontinuities in our inspection. We would have lost the advantage gained in using the P.E. penetrant in the first place!

One of the methods suggested on page 8-62 <u>is</u> prohibited because, using it, you would run that risk. Can you spot it now?

From page 8-62

Good for you! Never apply emulsifier with a brush.

Having successfully mastered that point, and having mastered the courage and energy necessary to perfectly accomplish this task, we now face Step Three, removal of excess penetrant from the surface.

Which of the following actions would get your informed O. K. for removal of excess fluorescent P. E. penetrant.

The maximum allowable water wash temperature will be 90°F . . . . Page 8-66

Excess penetrant may be wiped from the surface . . . . Page 8-67

Washing should be accomplished under black light . . . . Page 8-68

From page 8-65

Wait a minute now, we said your informed O. K. The maximum allowable water wash temperature is not 90°F, it is 110°F. Remember?

Return to page 8-65 and choose the correct statement for use with Step Three, removal of excess penetrant from the surface.

From page 8-65

You say "Excess penetrant may be wiped from the surface." That statement is not the one sought. The wiping method is seldom used with fluorescent type dyes. It is risky when P.E. penetrant is used because penetrant may be scraped away from shallow discontinuities. Water wash is the method used in removing penetrant excess.

Return to page 8-65 and select the action which correctly goes with Step Three, removal of excess fluorescent penetrant from the surface.

Good for you! Complete and adequate wash is more certainly obtained when excess fluorescent penetrants are washed under black light.

Although some discontinuities might be visible at the completion of this step, we would still have another step to take before we are ready to inspect the precision castings. It would be Step Four, application of the developer.

Somewhere along here in the process, we will want to dry the castings. When do you think we might want to use the drying oven?

Before the application of the developer . . . . Page 8-69

It would depend upon the type of developer . . . . Page 8-70

After the application of the developer . . . . Page 8-71

From page 8-68

You've jumped the gun! It is mighty important to use the dryers before the application of the developer .... if dry developer is to be used. But are we going to use dry developer in this case? You can see that we'll have to decide this point before we can decide when to use the drying ovens.

Let's now see what type of developer will be used. Our future actions will depend upon that choice. Your answer should be, "Depends upon the type of developer." Right?

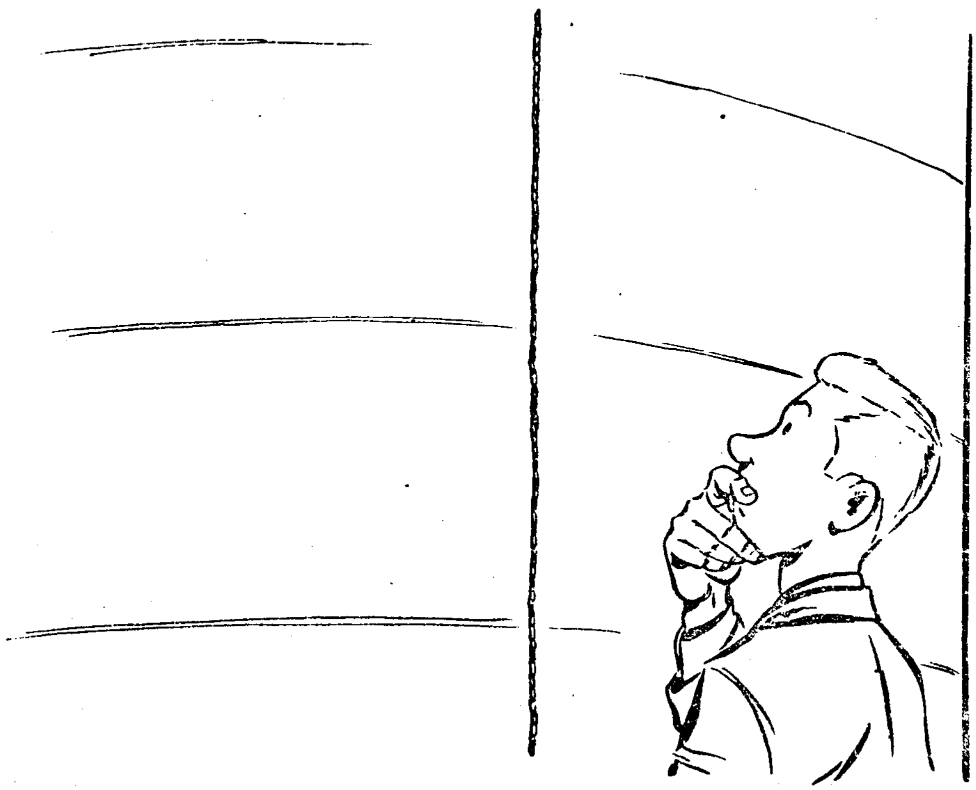
Turn to page 8-70.

From page 8-68

"Depends upon the type of developer," is correct.

Let's now turn to the last situation we've selected for use here — a weldment on a large tank.

Here is a picture of the weldment on the tank itself.



For checking the weldment on this large tank, a visible-dye, solvent-removable penetrant with a solvent-based wet developer will be specified.

Why do you suppose visible-dye, solvent-removable penetrant is suggested?

Because, as yet, we haven't used it as an example in this programmed instruction . . . . Page 8-72

Because it is more practical for this situation than the others . . . . Page 8-73

From page 8-68

You've jumped the gun! It is mighty important to use the dryers after the application of the developer. . . .If water-based wet developer is used. It wouldn't help a bit if it were used before. But are we going to use wet developer in this case? So far, we have not decided. You can see that we'll have to do just that before we can decide when to use the drying ovens.

Your answer would now be that use of the dryer before or after developer would... "depend upon the type of developer."

Let's see what type of developer will be used. Turn to page 8-70.

From page 8-70

Well, how 'bout that!

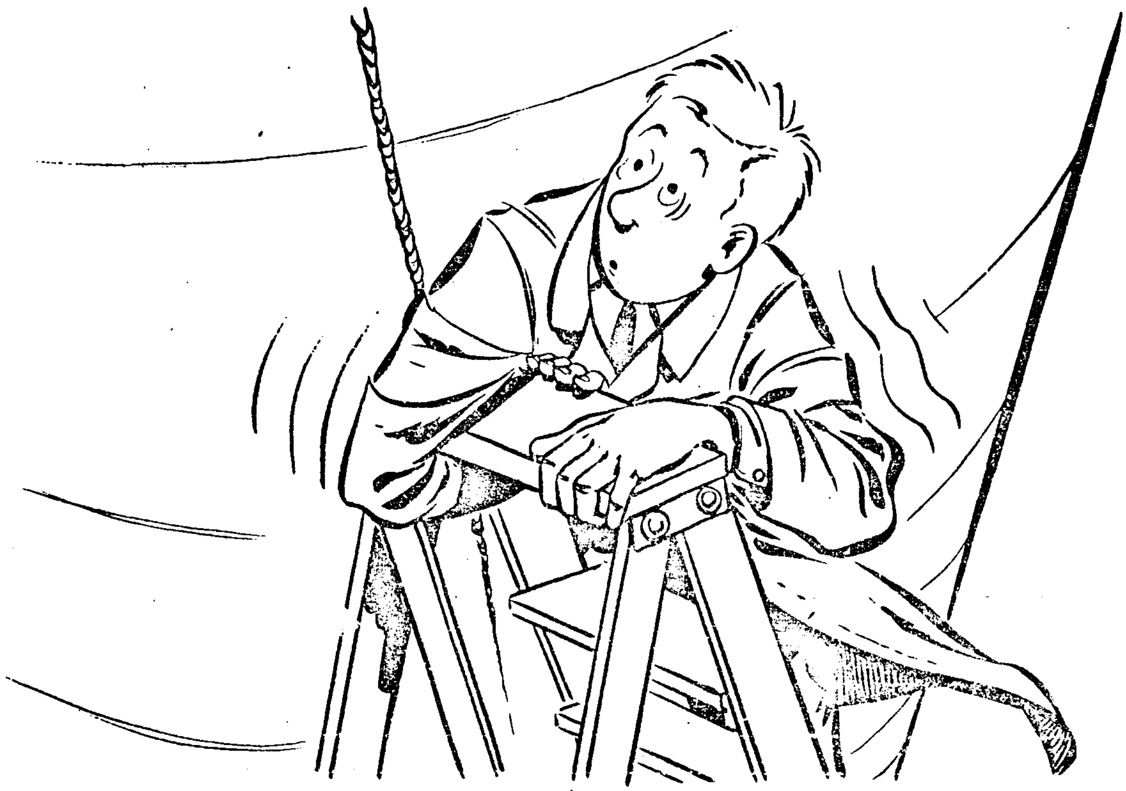
True. We haven't used non-fluorescent penetrants as an example, and — you guessed it — we're going to do so right about now. By the way, if you selected this little page because of curiosity....good for you. It may be dangerous for the feline cat, but for inspector type cats, it's a valuable attribute!

So, another point: If you're curious about the other selection choice, it was also correct! You'd use visible-dye penetrant because it provides for greater mobility than the other penetrants. And that's why we will use it.

So, let's do it. Turn to page 8-73.

From page 8-70

Right. This method is more practical for the situation. Look again where we must go to conduct this inspection.



We've got to check a weld on the tank. Fluorescent penetrants are not used because of the difficulty of obtaining proper conditions for use of black light. Solvent-removable penetrant is used since its application is more practical for this situation than a water wash. Because of these features, visible-dye, solvent-removable penetrants are considered to be more portable than the others.

A non-water based cleaning solvent will be used to free the weldment from contaminants and, after time has been allowed for evaporation of the cleaning solvent, the visible dye-penetrant will be applied. How? Well, there are many ways. Let's brush it on in this example, but remember spraying would be fine too. Dipping, you'll admit would be a bit awkward! We must be certain that the weldment is thoroughly covered. Which of the following rules is recommended?

Apply the penetrant at least one-quarter inch on either side of the weldment	Page 8-74
Apply the penetrant at least two inches on either side of the weldment	Page 8-75
Apply the penetrant at least one-half inch on either side of the weldment	Page 8-76

From page 8-73

You've selected the statement, "Apply the penetrant at least one-quarter inch on either side of the weldment" as representing the penetrant coverage recommended in this program. This is not correct. We have recommended at least one-half inch on each side of a weld. This was done because it was required in several actual test situations we've used here. Obviously, if you were testing a very small object, the entire object would be coated with penetrant. And, in some situations, one-quarter inch might (we stress again ... might) be adequate. It is recommended here, however, that you use at least one-half inch on either side of the weldment you want to test unless you are told to do otherwise.

We'll use one-half on each side of this tank weldment, wouldn't you say (since we recommended it)?

Turn to page 8-76.

From page 8-73

You evidently did not note our recommended one-half inch coverage. You have chosen to cover the weldment two inches on either side. In this situation one-half inch would have been OK, but you are to be commended. When in doubt, cover it well.

In this program, one-half inch minimum coverage is recommended on welds because it was required in many actual situations very similar to the make-believe situation we've created here. Use it unless directed to do otherwise. And remember, you are quite correct. When in doubt, cover it well. And that means more than one-half inch if you think it is necessary.

For the tank weldment, let's use one-half inch just for drill!

Please turn to page 8-76.

From page 8-73

With penetrant applied at least one-half inch on either side of the weldment, we are off to a good start on this important test. During our work with this penetrant, which of the following would be of particular concern to us in order to do a really good job on this tank?

Excess penetrant must not remain on the surface longer than the time recommended on the penetration time charts . . . . Page 8-77

Penetrant must be drained from all pockets and recesses before the next step . . . . Page 8-78

Penetrant temperature must be above 50°F . . . . Page 8-79

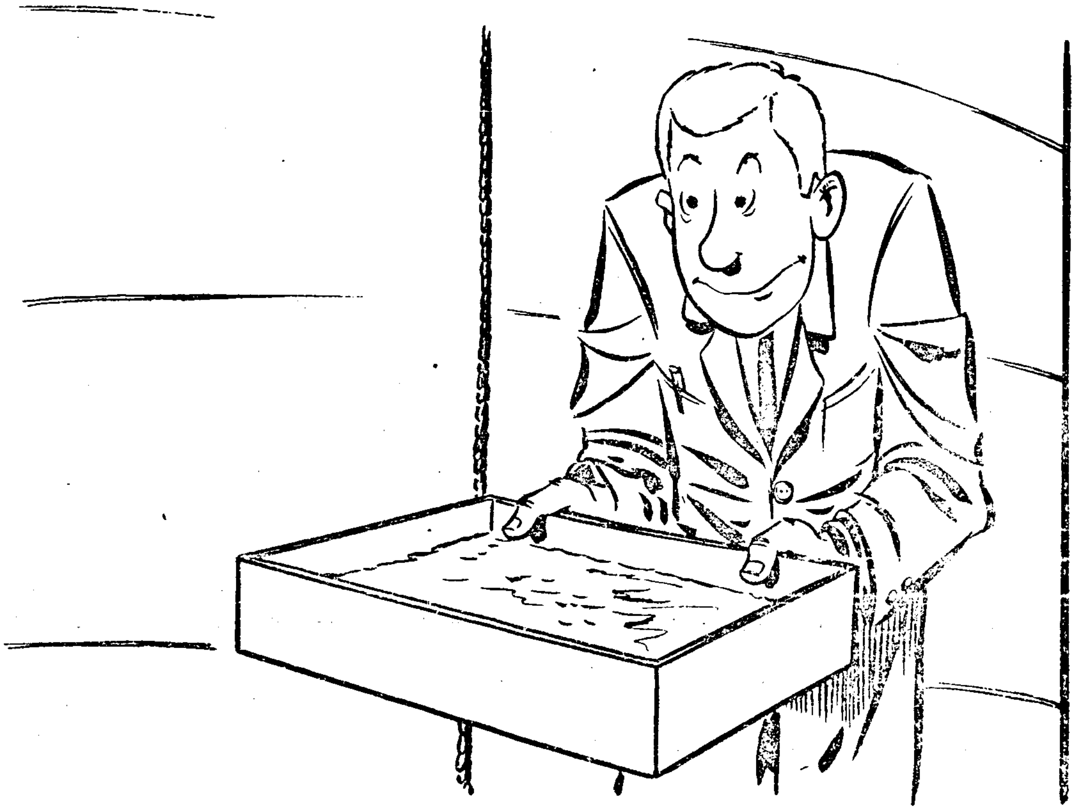
From page 8-76

Your concern for strict adherence to the penetration time charts is praiseworthy. But, remember this point: the times suggested on the charts are just the minimum allowable times. The only limit on the length of time the penetrant can be left on the item after these minimums have been met is set by practical economic considerations. If penetrant is left longer than necessary, it may be a little harder to remove and the procedure will take a little longer. Or the penetrant may have dried resulting in the requirement to reapply the penetrant. If we take longer in this task than we need, it costs money. The minimum suggested times will do just as well — and cost less. You should not be overly concerned with leaving penetrant on longer than recommended by the time charts. There is no must requirement in this area . . . so, your answer was not entirely correct. Why not return to page 8-76 and choose another? There's a better one there!

From page 8-76

No curve ball intended, but your answer was not correct.

You've stated that ". . . penetrant must be removed from all pockets and recesses before the next step." The next step will be the <u>developer application</u>. And, as you can readily imagine, we're not going to dip this one in a tank of wet developer.



When dipping was done, we were concerned with carrying penetrant over into the tank of wet developer. That won't be our problem here. Please return to page 8-76, look over the selections again, and choose one that will be of particular importance to us in this testing situation.

Good enough. If the penetrant is over 50°F when it is applied it will locate the discontinuities that are present and carry its visible red dye down into them. The penetrant time charts can be relied upon. When their minimum time requirements are satisfied, the excess will be removable. When using solvent-removable penetrants, this removal can be accomplished by wiping. This would be common practice in the situation we now face. The rag would probably be solvent dampened, not with water, but with another chemical cleaner. And in the next step, Step Four, a non-water based wet developer would probably be used. Common sense may explain the reason for wet developer. This would be a fine time to apply the developer with a spray gun! Now, this may not always be possible (or even permitted) but it clearly illustrates one other advantage found with wet developer use.

But why would this be apt to be a non-water based wet developer. For one reason only. The penetrant was mentioned as non-water based, water was not used to remove the penetrant excess, and now a non-water based wet developer is used. Get the picture? No water has been used. While this may not be necessary much of the time, you can see that this procedure will avoid the use of water.

Now turn to chapter 9 where we will discuss some of the major aspects of the equipment that is used in liquid penetrant testing.

CHAPTER 9 - TEST EQUIPMENT AND SPECIAL PURPOSE TEST MATERIALS.

In earlier chapters of this book we discussed thoroughly the procedures to be used in liquid penetrant testing. We are now going to take a brief look at some of the major aspects of the equipment that is used in penetrant testing.

Stationary Test Equipment

As you know, the equipment used in liquid penetrant testing may be either stationary or portable. Stationary equipment is that equipment which is normally used in one place. It is too bulky to be easily moved which means that the specimen under test is brought to the equipment to be tested.

The various items of stationary equipment, called stations, are listed here:

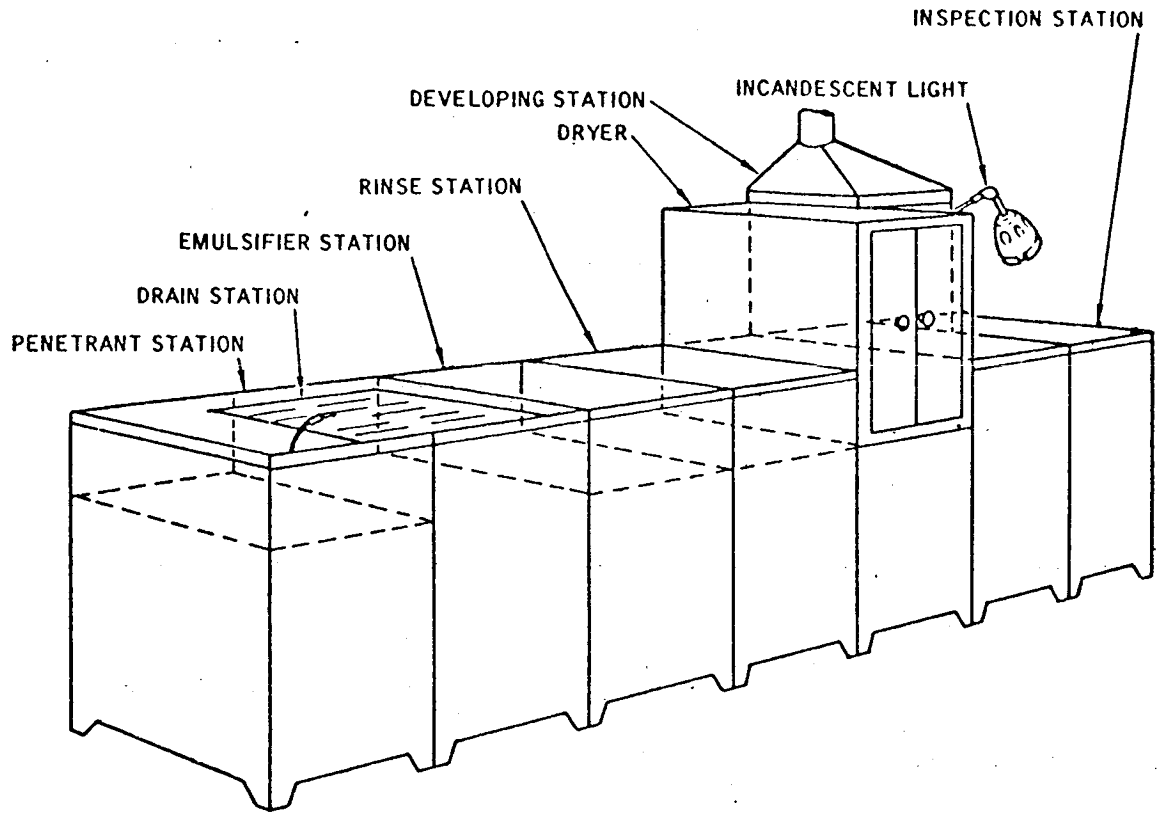
Pre-cleaning station (usually remote from penetrant test station).
Penetrant station (tank).
Drain Station (used with penetrant tank).
Emulsification station (tank).
Rinse station (tank and spray equipment).
Drying station (usually an oven type).
Inspection station (enclosed black-light booth or table with lighting facilities).
Post-cleaning station (usually remote from penetrant test station).

If you examine this list closely you will realize that each station performs one of the six steps that are required in a complete test.

Now turn to the next page.

From page 9-1

Here we show a typical stationary arrangement.



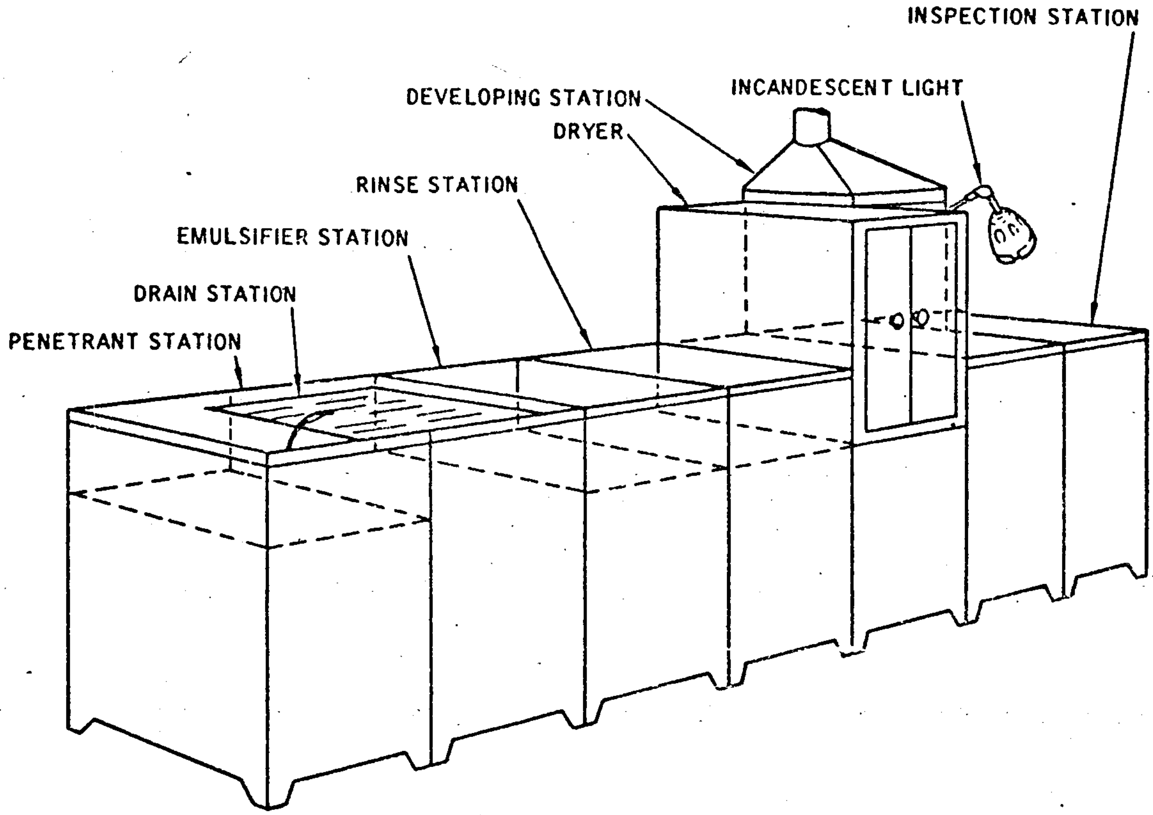
Stationary equipment is usually arranged in the order dictated by the testing process. Notice, for example, in the illustration above that the penetrant station is first, on the left, followed by the emulsification station, the rinse station, the dryer station, the developing station, and the inspection station. We can immediately tell that this arrangement is for a visible-dye (note the incandenscent lamp) post-emulsification penetrant (note the emulsifier tank ahead of the rinse tank).

Can you tell me which type of developer is used in this arrangement? There is a clue in the order of the stations.

A water-based wet developer is used . . . . Page 9-3
A dry developer is used . . . . Page 9-4

From page 9-2

You decided that this arrangement called for a wet developer. You've forgotton the procedural steps that are required when using a wet developer. If a wet developer were to be used, the dryer would be placed after the developing station. Lets' take a look at that arrangement again.



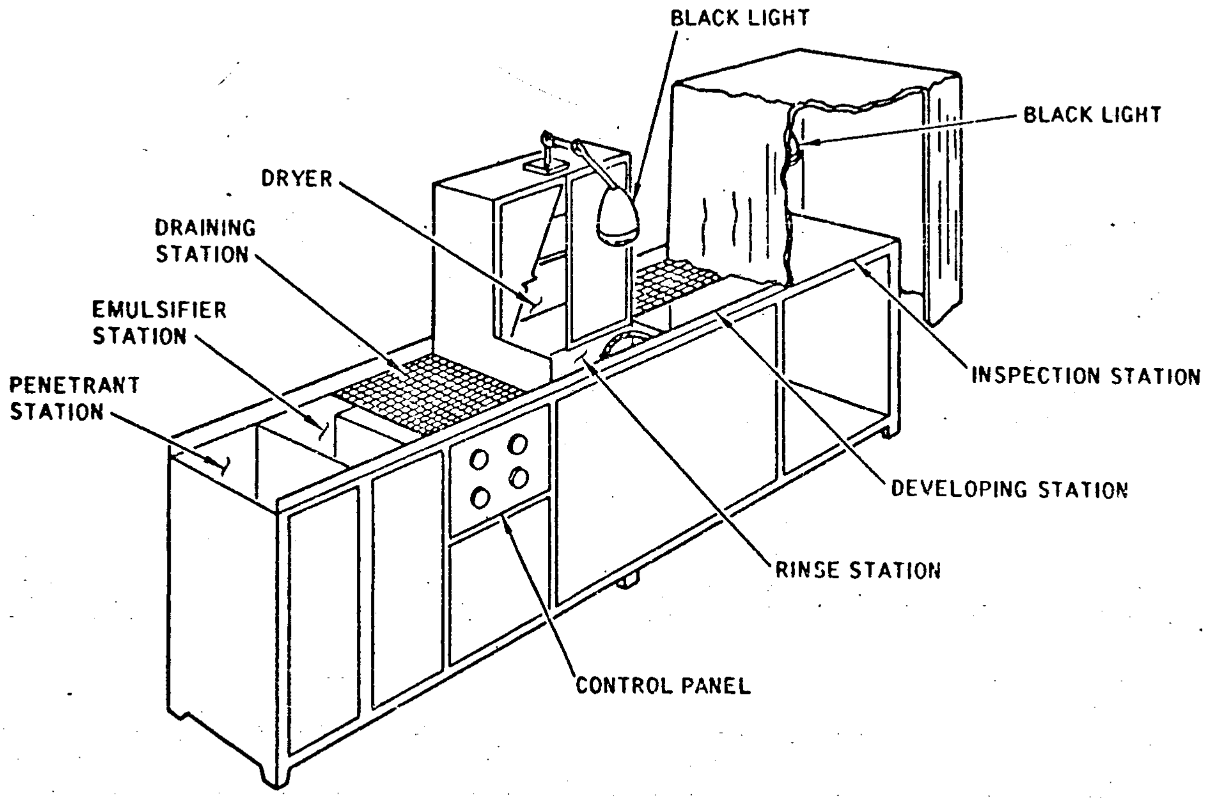
Note that the dryer appears in line before the developing station. Since the dryer is used first, the developer must be dry.

Now turn to page 9-4.

From page 9-2

Excellent. Since the dryer station is placed before the developer station, the developer must be a dry developer.

Now let's look at another arrangement of essentially the same stations.



In addition to changing the arrangement, the lighting has been changed.

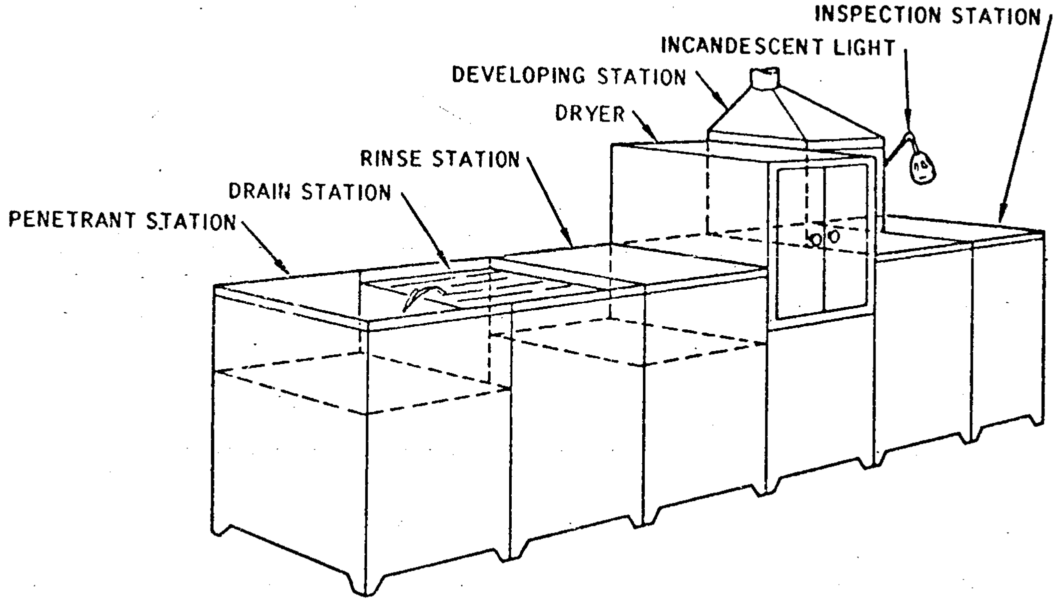
Which of the following test procedures fits this arrangement?

Fluorescent, post-emulsification penetrant/dry developer .... Page 9-5

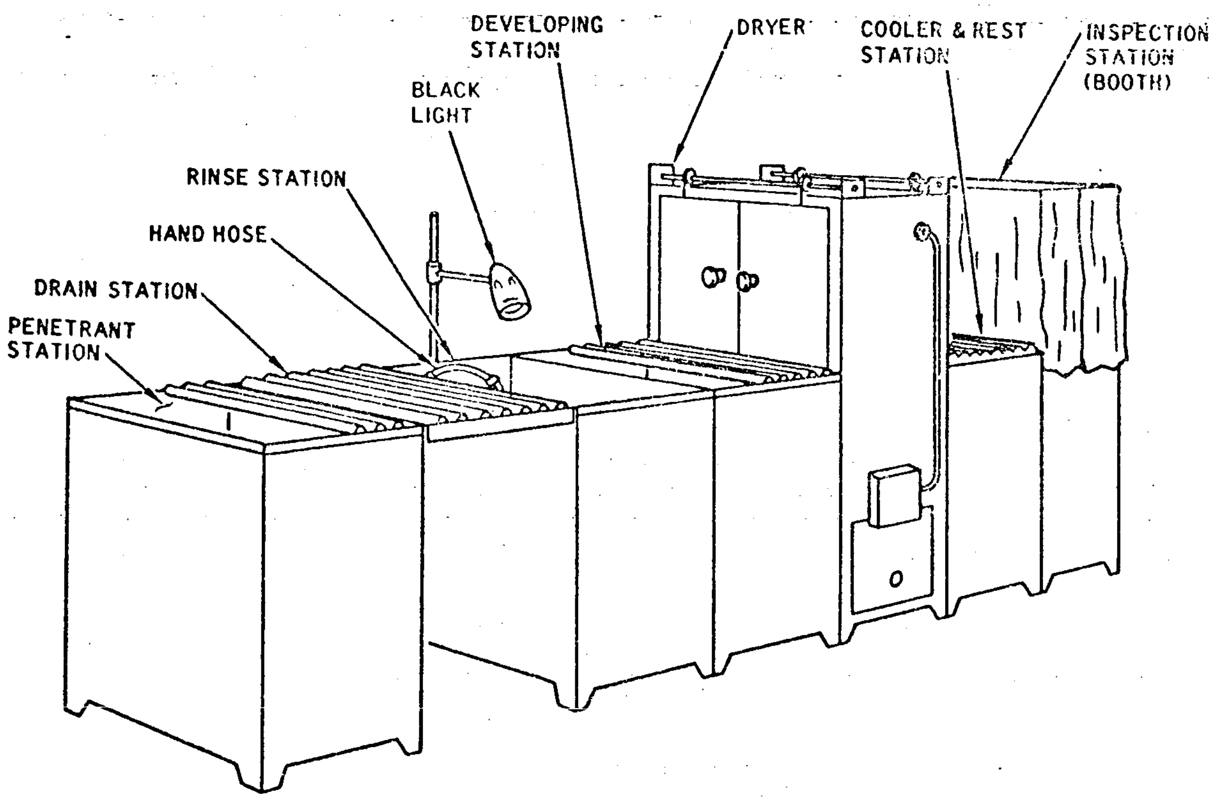
Fluorescent, post-emulsification penetrant/water-based wet developer .... Page 9-6

From page 9-4

Excellent - you are exactly right. Here are a couple of different arrangements for you to study. Note the difference in arrangement that is required for the differences in the testing process.



VISIBLE-DYE, WATER-WASHABLE PENETRANT/DRY DEVELOPER

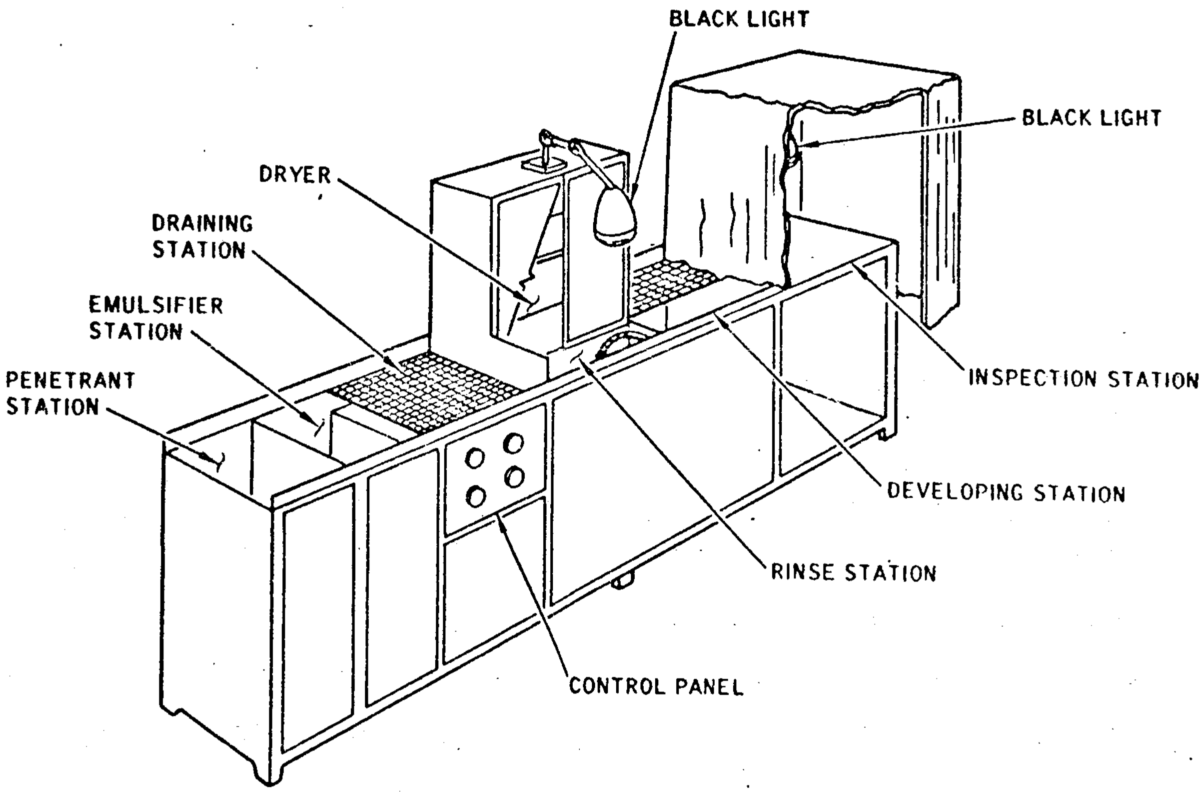


FLUORESCENT, WATER-WASHABLE PENETRANT/WET DEVELOPER

Now turn to page 9-7.

From page 9-4

Let's look at that arrangement again.



You selected the answer that says that this arrangement is set up for a water-based wet developer. This is not correct.

Let's review the procedure a little. When a dry developer is used the test specimen goes through the dryer prior to the application of the developer. This tells us that the developer is dry.

If the dryer is placed after the developer station, the developer is wet when applied and dried in the next step.

Now turn to page 9-5.

From page 9-5

Very good. What we have demonstrated on the first few pages is that the arrangement of the equipment is dictated by the process in use.

Each station will have additional equipment depending on the function of the station. Pumps are installed at penetrant, emulsifier, rinse, and wet-developer stations to agitate the solutions, to pump drain-off material into the proper tanks, and to power hand hoses. Hoses and applicators are provided at the required stations. Thermostats and thermometers are provided to control the temperatures of drying ovens and penetrant materials. Timers are provided to control penetrant, emulsifier, developing and drying cycles. Exhaust fans are used to facilitate removal of fumes and dust when testing is performed in closed areas. Hydrometers are used to measure the specific gravity of wet developers.

You may have noticed that there were no cleaning stations shown. Pre- and Post-test cleaning is usually accomplished in some area other than the test area. Briefly, cleaning equipment will consist of one or more of the following:

Detergent immersion tanks - when used require a suitable means of rinsing the detergent from the test specimen.

Vapor degreasing equipment - most effective in removing oil, grease, and similar organic contamination. In addition, the part is warmed which tends to drive off any moisture or solvents that may be caught in discontinuities.

Steam cleaning equipment - particularly adaptable to cleaning large unwieldly articles.

Solvent cleaning equipment - solvent cleaners are applied with an immersion technique or with a wipe-on wipe-off technique.

Turn to the next page.

Rust removing equipment - commercial acid or alkaline rust removers are used with equipment specified by the manufacturer of the remover.

Paint removing equipment - paint is removed by chemical strippers. The equipment is specified by the manufacturer of the remover.

Etching equipment - articles that have been ground or machined often require etching to remove metal covering discontinuities. Chemical etching processes use immersion tanks or wipe-on wipe-off techniques.

Turn to page 9-9.

From page 9-8

Portable Test Equipment

Portable penetrant test equipment is available for use in test situations where it is impractical to use stationary equipment. Both fluorescent and visible dye penetrant kits containing all the items and materials necessary for the complete testing process are available. When testing is required at a location remote from stationary equipment, or a spot test of an article is required, the portable kits are used. The liquids are usually contained in pressurized spray cans.

A visible-dye penetrant kit usually consists of a metal box in which is carried at least the following items:

Solvent or cleaning fluid
Visible-dye, solvent removable penetrant
Non-aqueous, wet developer
Wiping cloths and brushes

Judging from the above list would you say that the kit contains all the materials required to conduct a visible-dye penetrant test?

Yes .... Page 9-10
No .... Page 9-11

From page 9-9

Very good. The kit does contain all the equipment necessary to conduct a complete test using visible dye penetrant.

Naturally, if the test situation requires that fluorescent penetrant be used, the above kit would be useless. Hence the requirement for a portable fluorescent test kit.

The fluorescent-test kit usually contains the following (again in pressurized cans where possible):

Solvent or cleaning fluid
Fluorescent, solvent-removable penetrant
Non-aqueous wet developer
Dry developer
Wiping cloths and brushes
Portable black light and transformer

The fluorescent test kit should contain all of the items and materials that are required for a complete fluorescent test.

True . . . . Page 9-12
False . . . . Page 9-13

From page 9-9

We have no idea what you may consider is missing from the list. But let's say this - if there is anything missing from the kit that you consider to be required to complete the test then get some and add it to the kit. To be effective, the kit must contain everything that is necessary to perform a complete test.

Now turn to page 9-10 and continue.

From page 9-10

Right - an incomplete test kit can cause considerable loss of time in a remote testing situation. Always make sure that the kit contains everything needed to complete the test.

Specialized Penetrant-Test Materials.

We have discussed rather thoroughly the use of penetrants under normal situations in previous chapters. Now we want to point out some situations where more specialized test materials are required.

Liquid Oxygen Compatibility.

Liquid Oxygen (LOX) is used in many modern day applications. By itself, liquid oxygen is non-explosive, but whenever it comes in contact with a combustible material an explosive situation exists and the slightest spark or jar can set off a violent reaction. In some cases the explosion is spontaneous - nothing else is required to set it off.

It is very important then that any articles that are to be ultimately used in any system handling liquid oxygen be entirely free from any combustible substances. For this reason such articles are subjected to extensive cleaning processes after manufacture. During manufacture and testing of the article, special care is taken not to contaminate the article with combustible materials.

A valve that is to be used to control the flow of liquid oxygen in a LOX handling system must be kept free of any materials that will burn. During manufacture of the valve no combustible materials are used on the valve. This helps to assure that the valve is free of such contaminants.

Suppose, for example, the above mentioned valve requires a hole drilled in the body of the valve. Can oil be used to cool the drill?

Yes .... Page 9-13

No .... Page 9-14

From page 9-12

No, no, no. Oil is combustible - it will burn. If we used oil to cool the drill we would be contaminating the valve. It would be possible to leave minute traces of oil on the valve in spite of any cleaning procedure used. Then, when the valve was installed in the liquid oxygen system, these traces of oil could be the cause of an explosion in the system.

In order to be absolutely certain that the valve is not contaminated we avoid using any materials during the manufacture of the valve that are not compatible with liquid oxygen. The same rules apply during the liquid penetrant testing processes.

Now turn to page 9-14.

From page 9-12

Very good. The use of oil on this valve is prohibited since the valve will be used in a liquid oxygen system.

When such articles are to be tested by penetrant methods, only those penetrant testing materials can be used that do not contain combustible materials. We can use only those penetrant materials that are approved as being compatible with liquid oxygen. In order to have been approved as being liquid oxygen compatible, each batch of materials has undergone an extensive test. In brief, the "Liquid Oxygen Compatibility Test" requires that a specimen of the substance be placed in a super-clean cup filled with liquid oxygen. Under carefully controlled conditions this specimen is given a blow of a specified force applied by dropping a weight a given distance onto an impact pin. The test operator observes the impact for any reaction between the substance and the surrounding oxygen. You do not need to know the details of this test procedure but you should know when there are requirements for the "Liquid Oxygen Compatibility Impact Sensitivity Test".

When using liquid penetrants on the LOX valve we have been discussing, you must be sure that the penetrant testing materials are ______________________________.

..... free from any combustible materials .... Page 9-15

..... cleaned from the valve after testing .... Page 9-16

From page 9-14

You are absolutely right. The penetrant materials used must be free from any combustible materials. This is always the first consideration.

Then the first step to remember when testing articles to be used in LOX systems is - use only those penetrants, emulsifiers, and developers that are currently approved for use on liquid oxygen systems by specifications and directives.

When such oxygen compatible materials are used, the inspector must take care that these materials do not become contaminated with combustible materials. Therefore, when using bulk materials, he should remove only enough material from the original container to test the article immediately on hand. Any material remaining after the test shall be discarded - not returned to the original container. Any container, brush, spray system, etc., must be specially cleaned prior to use with LOX compatible materials to avoid contamination of the materials.

The test procedure using LOX compatible materials is identical to the procedure using any other penetrant materials. The oxygen compatible penetrant materials are usually water washable and excess penetrant removal should be accomplished by use of water.

When using liquid penetrant testing on articles to be used in LOX systems, the test materials must be . . . . .

. . . . approved for use on LOX systems by specifications . . . . Page 9-17

. . . . applied by a different method than is used in an ordinary situation . . . . Page 9-18

From page 9-14

You are about half right, but half right isn't nearly good enough. Granted, all test materials must be cleaned from the valve after the test and inspection but this is not enough to assure that there are no contaminants remaining on the valve.

In order to assure that there are no contaminants on the valve we take care not to add any. The testing materials used must be free of any combustible materials.

Now turn to page 9-15.

From page 9-15

Right. Only those penetrants, emulsifiers, and developers that have been approved as being LOX compatible by current specifications and directives can be used. Special care must be taken to see that the test materials do not become contaminated with combustible materials during their use.

The easiest way to prevent contamination of LOX-compatible, penetrant materials is to use the approved materials furnished in pressurized cans.

If bulk LOX compatible materials are to be used, the test operator must . . . .

. . . . clean each item of test equipment before use . . . . Page 9-19

. . . . use the same equipment he has used for ordinary testing . . . . . . Page 9-20

The use of LOX compatible testing materials does not require any change from the ordinary test procedures as you have indicated. Every step is accomplished in exactly the same way. There are only two additional requirements: 1) The materials used must be approved for use on LOX systems; 2) Care must be taken to assure that the materials do not become contaminated. Turn to page 9-17 for more information on this subject.

From page 9-17

You are right. One source of possible contamination is the equipment being used. Therefore, each piece of equipment used in the testing process should be cleaned prior to use with LOX compatible penetrants.

After testing, the article must be cleaned with washes that do not contain any combustible materials. Water is most often used. Extra care must be taken to remove all penetrant possible.

Whenever the LOX compatible testing materials are suspected of being contaminated with combustible materials, and at other times as may be specified by applicable directives, they must be retested for compatibility with liquid oxygen. This "Liquid Oxygen Compatibility Impact Sensitivity Test" is extremely complex - hence the need for care in preventing any possible contamination.

Any cleaning material may be used in the post test cleaning process.

True .... Page 9-21
False .... Page 9-22

From page 9-17

Well, you are right but this is not the best answer to the question. The same equipment may be used but when it is to be used with LOX compatible penetrants, it must be cleaned first.

Contaminated equipment would contaminate the materials handled by the equipment. The penetrants and cleaning materials used for ordinary penetrant testing do contain combustible substances. Any traces of these substances on the equipment will contaminate the LOX-compatible penetrant materials. Therefore, a careful cleaning of the equipment is required.

Now turn to page 9-19.

From page 9-19

Slow down a bit. You have selected the answer that says "Any cleaning material may be used in the post-test cleaning process". This is not correct.

Remember - when using LOX compatible penetrants we are trying to avoid using any materials that are combustible. Many cleaning materials contain combustible materials - these cannot be used.

You can use only those cleaning materials that do not contain any combustible materials.

Now turn to page 9-22.

From page 9-19

Right! You can use only those cleaning materials that do not contain any combustible materials.

In review - there are three facts that you must remember when testing articles that are to be used in a liquid oxygen system:

1) Use only those testing materials that are approved as being liquid oxygen compatible.
2) All equipment used is to be cleaned prior to use.
3) Particular attention is to be paid to cleaning all traces of the penetrant materials from the article after testing is complete.

Other Special-Purpose Penetrant Materials

In addition to the LOX compatible penetrants, other special penetrants have been developed for particular uses. Nickel alloys, for example, are adversely affected by the presence of sulphur or chlorine. These elements are present in most of the more common penetrant materials. Therefore, for such use, special penetrant materials are available which are sufficiently free from such elements (sulphur, chlorine) that they are acceptable for use in penetrant testing. Use of these special penetrants is specified in applicable directives. Such penetrants are specified to avoid all possibility of residual amounts of the objectionable elements remaining on the surface of such alloys.

The penetrants that are used on steel can be used on nickel-steel.

True .... Page 9-23

False .... Page 9-24

From page 9-22

Your answer indicates that you do not fully understand what an alloy is. An alloy is a mixture of two or more different metals. Briefly, alloys are used because the properties of the alloy - strength, weight, hardness, etc., are different than the properties of the separate metals used in the alloy.

Whenever the alloy is a combination of nickel and any of the other metals, special purpose penetrant materials must be used in the penetrant testing process. Therefore, the common penetrants used on steel cannot be used on the nickel-steel alloy.

Now turn to page 9-24.

From page 9-22

Very good! Since nickel-steel is a nickel alloy we must use the special-purpose penetrants that are specified for nickel alloys.

In the penetrant testing of plastics, care must be taken to be sure that the penetrant materials will not attack the plastic. When in doubt - test the materials on a piece of scrap.

The following are a few more examples of the use of special-purpose penetrants. These examples are provided here simply to make you aware of the fact that such special-purpose penetrants do exist so that you will be able to recognize such an application should you ever encounter it. It is beyond the scope of this book to cover all possible applications of penetrants.

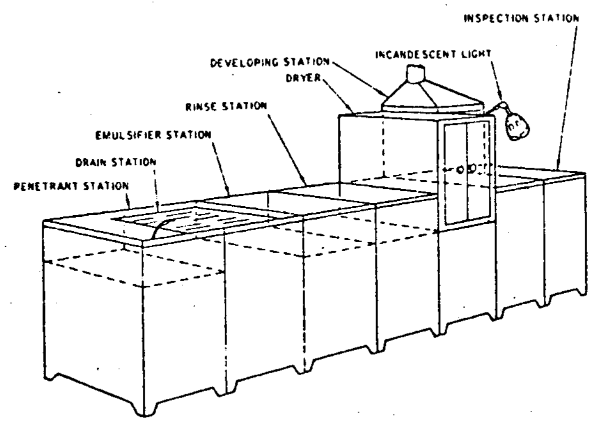
We have described fluorescent penetrants that glow with a yellow-green color. There are other fluorescent materials that glow with a red or blue color. For example there is a red fluorescent penetrant that is useful to furnish a contrast for the natural blue fluorescent of petroleum oils. There is a blue fluorescent dry concentrate that uses water as a penetrant. This provides a cheaper penetrant where large volumes of the penetrant are required and where a marked contrast from the natural blue fluorescence is not a problem.

Another special-purpose penetrant combines a harmless dye in edible oils and is used in testing food processing machinery.

Special formulas are devised to provide satisfactory performance under exceptionally high temperature conditions. These can be used for detecting defects in welds while the welded metal is still at temperatures so high that none of the conventional penetrants can function.

Now turn to page 9-25 for a review of this chapter.

From page 9-24



1. The equipment shown here is called ________________ (stationary, portable) equipment.

5. fluorescent

6. Portable test kits do not contain all the materials and equipment required for a complete test. (True - False).

10. compatible

11. When testing articles to be used in an environment of liquid oxygen, only those penetrant materials that are approved by ________________ as being compatible with liquid oxygen can be used.

15. combustible

16. Careful post-test cleaning of LOX handling equipment is required. (True - False)

1. stationary

2. Each portion of stationary equipment that performs one step of the testing process is called a ______________________.

6. False

7. The presence of any combustible materials in an atmosphere of liquid oxygen creates an explosive situation. Therefore, any articles that are to be used in a system handling liquid oxygen must be free of any ___________________ substances.

11. specification (directive)

12. Penetrant testing equipment can be a source of contamination of LOX compatible penetrants because they might have traces of ____________ materials.

16. True

17. LOX compatible penetrants are only one example of special purpose penetrants. Nickel alloys also require __________ ____________ penetrants.

2. station

3. The stations are arranged in an order dependent on the test ____________ in use.

7. combustible

8. The more common penetrant test materials contain combustible elements. Therefore, they are not used to test articles that will be used in ________ ________________ systems.

12. combustible

13. Any combustible materials on penetrant testing equipment can contaminate the LOX compatible penetrant. Therefore, the equipment must be ____________ prior to the use with LOX compatible penetrants.

17. special purpose

18. Sulphur and chlorine are elements present in the more common penetrant materials. These elements have an adverse effect on ________________ alloys.

3. process

4. When an article is too large to be tested with stationary equipment, ________________ equipment may be used.

8. liquid oxygen

9. The penetrant materials used to test LOX handling articles are compatible with liquid oxygen. They do not contain ________________ materials.

13. cleaned

14. In cleaning equipment prior to use with LOX compatible materials only those cleaning materials that are ________________ with liquid oxygen may be used.

18. nickel

19. Nickel alloys require the use of special-purpose penetrants that are relatively free of ________________ and ________________.

4. portable

5. Portable test kits are available for both ________________ and visible-dye penetrant kits.

Return to page 9-25, frame 6.

9. combustible

10. Penetrant materials that are approved by specification for use on LOX handling articles are ____________________ with liquid oxygen.

Return to page 9-25, frame 11.

14. compatible

15. Post-test cleaning of liquid oxygen handling equipment is to be accomplished only with those cleaning materials that do not contain any ______________materials.

Return to page 9-25, frame 16.

19. sulphur, chlorine

You have now completed the review of Chapter 9. Now, turn to the next page.

From page 9-29

You have just completed the programmed instruction course on Liquid Penetrant Testing.

Now you may want to evaluate your knowledge of the material presented in this handbook. A set of self-test questions are included at the back of the book. The answers can be found at the end of the test.

We want to emphasize that the test is for your own evaluation of your knowledge of the subject. If you elect to take the test, be honest with yourself - don't refer to the answers until you have finished. Then you will have a meaningful measure of your knowledge.

Since it is a self evaluation, there is no grade - no passing score. If you find that you have trouble in some part of the test, it is up to you to review the material until you are satisfied that you know it.

Turn or rotate the book 180° and flip to page T-1 at the back.

LIQUID PENETRANT TESTING

SELF-TEST

1. Water-Washable liquid penetrants differ from Post-Emulsification penetrants in that they:

   a. Can only be used on aluminum alloy articles.

   b. Need not be removed from surfaces prior to development.

   c. Have an oily base.

   d. Do not need an emulsifier added.

2. Penetration time periods can be obtained with the aid of prepared charts.

   a. True   b. False

3. When P.E. penetrant is used, the times recommended in the penetration time charts are:

   a. Not so important as emulsification times.

   b. More important than emulsification times.

   c. Equal to emulsification times in importance.

4. Liquid penetrant tests can be used to detect:

   a. Internal porosity in castings.

   b. Corrosion wall thinning in pipes and tubes.

   c. Fatigue cracks in magnesium alloy parts.

   d. Carbon content of steels.

5. Presence of the following substances on test articles can interfere with fluorescent liquid penetrant testing:

   a. Oil or grease.   c. Traces of water.

   b. Acids or chromates.   d. All of these.

6. Why should sandblasting with coarse sand and/or shot be avoided on articles during surface preparation?

a. Sand or shot may be forced into the discontinuity.

b. The discontinuities might be closed.

c. The surface may not be cleaned.

7. If you are using a Fluorescent, Post-Emulsification penetrant and a water-based wet developer, which of the following would you do?

a. Use a dryer after developer application

b. Strip away a metallic plating after vapor degreaser cleaning.

c. Wash away excess penetrant under black light prior to emulsification application.

8. Black light will cause injury to the eyes.

a. True   b. False

9. A discontinuity, undetectable with liquid penetrants at one stage in production, could be detected with liquid penetrants at a later stage in production.

a. True   b. False

10. The function of the emulsifier in the Post-Emulsification penetrant is to:

a. Drive the penetrant into deep, tight cracks more rapidly.

b. Add fluorescent dye or pigment to the penetrant.

c. Provide a coating to which dry powder developer can adhere.

d. Render surface penetrant water-washable.

11. When you use Post-Emulsification penetrant, the timing is most critical during the:

a. Penetration time.   c. Excess penetrant removal.

b. Emulsification time.   d. Dwell time.

12. To detect shallow defects with Post-Emulsification methods, the emulsification time should be long enough to:

a. Mix emulsifiers with penetrant in the discontinuities.

b. Mix emulsifiers with excess penetrant.

c. Mix emulsifiers with all penetrant.

13. Fluorescent and visible-dye penetrants are both effective on non-magnetic materials.

    a. True b. False

14. Hot air drying of articles during liquid penetrant testing is best done in drying ovens operating in the temperature range from:

    a. 75° to 125°F c. 130° to 225°F
    b. 50° to 100°F d. 250° to 325°F

15. Articles do not need to be completely dried before application of dry developers, since the powder will dry them anyway.

    a. True b. False

16. Liquid penetrant indications of a press fit are considered a . . .

    a. discontinuity indication. c. non-relevant indication.
    b. defect indication.

17. Most wet developers are fluorescent.

    a. True b. False

18. The length of time the emulsifier remains on the article is very important if detection of shallow discontinuities is desired.

    a. True b. False

19. Washing excess fluorescent penetrants from a surface is a critical operation and should be conducted under black light if possible.

    a. True b. False

20. A thick coat of wet developer is better than a thin coat of developer for the detection of small discontinuities.

    a. True b. False

21. Penetrant tests will show defects open to the surface which are free from oil, grease, dirt, water, and other contaminants.

    a. True b. False

22. Glass and ceramics, as well as metals, can be inspected with Fluorescent, Water-Washable penetrants.

    a. True   b. False

23. If too long an emulsification time is used, which of the following would most likely result.

    a. Non-relevant discontinuity indications.
    b. Shallow discontinuity indications are lost.
    c. Excess penetrant would remain after the wash.

24. Sub-surface discontinuity indications are detectable with a magnetic particle inspection.

    a. True   b. False

25. A liquid penetrant test is one of the following:

    a. A search for sub-surface discontinuities.
    b. A nondestructive test method.
    c. A search for unhealed porosity.

26. A penetrant test is not the first choice when testing porous surfaces because:

    a. Magnetic particle methods do a better job.
    b. Filtered particle methods do a better job.
    c. Liquid penetrant methods would not produce any indications.

27. When should magnetic particle tests replace liquid penetrant tests?

    a. When sub-surface discontinuities are suspected in aluminum articles.
    b. When sub-surface discontinuities are suspected in iron forgings.
    c. When excessive porosity is suspected in ceramic insulators.

28. Removal of excess water-washable penetrant is best accomplished with a coarse, forceful water spray.

    a. True   b. False

29. Developers are not used to:

    a. Blot penetrant from discontinuities.

    b. Provide an image of a discontinuity.

    c. Add fluorescence to penetrants.

30. The addition of emulsifiers is necessary before visible-dye, solvent-removable penetrant excess can be removed.

    a. True b. False

31. Visible-Dye penetrants have one of the following as an advantage over other penetrants.

    a. They produce a yellow-green discontinuity image under black light.

    b. They can be used reliably at temperatures below 50°F.

    c. They are highly portable.

32. The maximum allowable water temperature suggested for best penetrant removal is:

    a. 50°F b. 225°F c. 110°F

33. Visible-Dye, Solvent-removable penetrant excess is best removed by which of the following:

    a. A forceful water spray.

    b. A soft, bristled brush.

    c. A penetrant remover recommended by the manufacturer of the penetrant.

34. Place a check mark opposite the methods listed below which are surface cleaning methods for liquid penetrant testing.

________ vapor degreasing	________ volatile solvent
________ shot-blasting	________ sandblasting
________ alkaline cleaning	________ all of above

35. A red against white discontinuity image is most apt to be seen when which of the following occurs?

    a. Dry developers are used.
    b. Fluorescent, P.E. penetrants are used.
    c. Visible-Dye penetrants are used.

36. Which of the following is the one true limitation to a liquid penetrant test?

    a. It cannot be used on ferro-magnetic materials.
    b. It cannot locate sub-surface discontinuities.
    c. It cannot be used on porous materials.
    d. It cannot be used on non-metallic surfaces.

37. Wire-brushing of surfaces is an acceptable method for use during surface preparation especially for removing metallic plating.

    a. True b. False

38. Penetrant diffusion into the developer is necessary in order to make the penetrant water-washable.

    a. True b. False

39. A water wash that is too hot is dangerous to test results because:

    a. It may remove some of the penetrant from the discontinuities.
    b. It may remove fluorescent dyes from the penetrant.
    c. It may form water contaminants in the smaller discontinuities.

40. The old "Oil and Whiting" liquid penetrant test process relied upon:

    a. A Wet Developer c. Neither a. nor b.
    b. A Dry Developer d. Both a. and b.

41. When conducting Step One you should . . . .

    a. Clean articles and then remove any metallic platings.
    b. Remove metallic platings and then clean articles.
    c. Never apply a cleaner with a brush.

42. The recommended development time for dry developers is:

    a. The minimum time stated on the charts.
    b. The time most suitable for operator convenience.
    c. Half the minimum time stated on the penetrant time chart.

43. Which of the following is not permitted?

    a. Application of emulsifier by dipping.
    b. Application of developer by spraying.
    c. Removal of penetrant with water.
    d. Application of emulsifer with a brush.

44. The proper emulsification times will be supplied by the emulsifier manufacturer.

    a. True   b. False

45. When a penetrant is below the minimum temperature, the article or the penetrant may be heated to raise its temperature during application.

    a. True   b. False

46. When small discontinuities are sought, the penetration times will be . . . .

    a. . . . longer than when only larger discontinuities are sought.
    b. . . . shorter than when only larger discontinuities are sought.
    c. . . . the same as when larger discontinuities are sought.

47. The natural force relied upon to the greatest extent in liquid penetrant testing is called:

    a. Gravity   c. Capillary Action
    b. Boil's Law   d. Penetrant's Practice

48. Penetrant temperature will affect:

    a. The penetration time chosen.
    b. The usefulness of the time charts.
    c. Both of the above.

49. On which of the following would liquid penetrant be the least successful?

a. Polyurethane foam
b. Steel
c. Plastic
d. Glass
e. Aluminum

50. It is necessary for the part to remain submerged in the penetrant throughout the penetration period.

a. True
b. False

51. Which of the following is the best penetrant for detecting shallow discontinuities?

a. Fluorescent, Post-Emulsification
b. Fluorescent, Water-Washable

52. List at least two major safety considerations mentioned in this program that should be observed by personnel in order to avoid injury or sickness.

a. ________________________________

b. ________________________________

53. Best fluorescent discontinuity indications can be seen by the test operator immediately after he enters the black light booth.

a. True
b. False

54. Which of the following are suggested as minimum penetrant coverage?

a. One-half inch either side of a weldment and one inch around any other area to be tested.
b. One inch either side of a weldment and two inches around any other area to be tested.
c. One inch either side of a weldment and one inch around any other area to be tested.

55. The penetration times suggested will be . . .

a. . . . minimums.
b. . . . maximums.
c. . . . averages.
d. . . . guesses.

56. Black light is considered ultraviolet light.

a. True   b. False

57. A thick layer of wet developer on an article is better than a thin layer for showing very fine cracks.

a. True   b. False

58. When visible-dye, solvent-removable penetrants are used, one of the following is a must:

a. Cloths and towels recommended by penetrant manufacturer must be used.
b. Excess penetrant must be removed indoors.
c. Cloths used must be lint free.

59. Number the actions below using numbers 1 through 6 in the order they would occur when performing a penetrant test with Fluorescent, Water-Washable penetrant and a Water-Based Wet Developer.

_____ inspection   _____ dry in drier   _____ apply wet developer
_____ prepare surface   _____ apply penetrant   _____ remove excess penetrant

60. Which of the following best defines the Development Time?

a. The time from excess penetrant removal to the Inspection.
b. The time from Developer Application to the Inspection.
c. The time from Developer Application to Post-test Cleaning.

61. Extremely large articles are usually tested with . . . . . .

a. . . . . stationary test equipment
b. . . . . portable test equipment
c. . . . . LOX compatible materials

62. The arrangement of stationary liquid penetrant test equipment must depend on . .

a. . . . . the equipment available
b. . . . . the test procedure to be used
c. . . . . the judgement of the operator

63. Portable test kits must contain all the materials and equipment required for a complete test.

a. True b. False

64. Approved LOX compatible penetrant materials do not contain any . . . . .

a. . . . . fluorescent dyes

b. . . . . cleaning materials

c. . . . . combustible materials

65. When LOX compatible penetrant materials are used the equipment must be . . .

a. . . . . cleaned prior to use

b. . . . . cleaned after use

c. . . . . approved by specifications

66. The sulphur and chlorine found in common penetrant materials are detrimental to:

a. aluminum alloys c. nickel alloys

b. iron castings

Turn to the next page for Self-Test answers.

ANSWERS FOR SELF-TEST

	Page No. Ref.		Page No. Ref.
1. d	4-10	28. a	4-8
2. a	3-13	29. c	5-1
3. a	4-12	30. b	4-5
4. c	1-6	31. c	3-6
5. d	2-2	32. c	4-8
6. b	2-7	33. c	4-5
7. a	5-20	34. all of above	2-2
8. b	3-6	35. c	3-6
9. a	1-7	36. b	1-6
10. d	4-10	37. b	2-4
11. b	4-12	38. b	5-2
12. b	4-17	39. a	4-8
13. a	7-1	40. b	1-8
14. c	5-8	41. b	2-4
15. b	5-20	42. c	5-24
16. c	6-2	43. d	4-10
17. b	5-6	44. b	4-18
18. a	4-12	45. a	3-24
19. a	4-20	46. a	3-16
20. b	8-44	47. c	3-1
21. a	2-2	48. c	3-24
22. a	7-1	49. a	7-1
23. b	4-12	50. b	3-10
24. a	7-3	51. a	4-13
25. b	1-1	52. Avoid skin contact with cleaning solvents Avoid breathing cleaning solvent fumes. Do not smoke near cleaning solvent fumes. (or any similar answers.)	2-6
26. b	7-1		
27. b	7-1		

		Page No. Ref.
53.	b	8-53
54.	a	3-10
55.	a	3-13
56.	b	8-53
57.	b	8-44
58.	c	4-5
59.	1. Prepare surface	
	2. Apply penetrant	
	3. Remove excess penetrant	
	4. Apply wet developer	
	5. Dry in drier	
	6. Inspect	6-1
60.	b	5-24
61.	b	9-9
62.	b	9-2
63.	a	9-9
64.	c	9-12
65.	a	9-19
66.	c	9-22